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THE THEORY OF INTERNAL STRESS IN GRAPHICAL STATICS.

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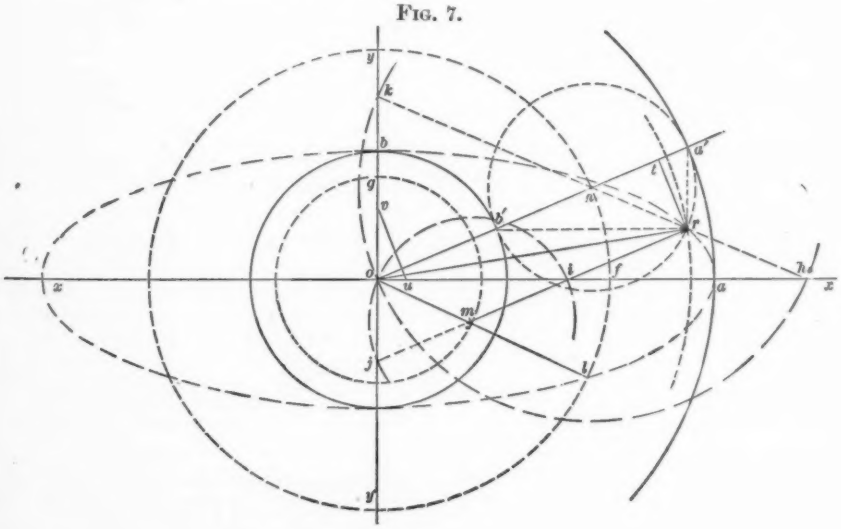
II.

PROBLEMS IN PLANE STRESS.

PROBLEM 1.—When a state of stress is defined by principal stresses which are of unequal intensity and like sign, *i.e.*, in a state of oblique stress, to find the intensity and obliquity of the stress at *o* on any assumed plane in the direction *uv*.

FIG. 7.



In Fig. 7 let the principal stresses at o be a on yy and b on xx; and on some convenient scale of intensities let $oa=a$ and $ob=b$. Let uv show the direction of the plane through o on which we are to find the stress, and make on perpendicular uv. Make $oa'=oa$ and $ob'=ob$. Bisect $a'b'$ at n, then $on=\frac{1}{2}(a+b)$ and $na'=\frac{1}{2}(a-b)$. Make $xol=xon$ and complete the paralellogram $nomr$; then is the diagonal $or=r$ the resultant stress on the given plane in direction and intensity.

The point r can also be obtained more simply by drawing $b'r \parallel xx$ and $a'r \parallel yy$.

We now proceed to show the correctness of the constructions given and to discuss several interesting geometrical properties of the figure which give to it a somewhat complicated appearance, which complexity is, however, quite unnecessary in actual construction, as will be seen hereafter. It has been shown that a state of stress defined by its two principal stresses a and b can be separated into a fluid stress having a normal intensity $\frac{1}{2}(a+b)$ on every plane, and a right shearing stress whose principal stresses are $+\frac{1}{2}(a-b)$ and $-\frac{1}{2}(a-b)$ respectively.

Since the fluid stress causes a normal stress on any given plane, its intensity is rightly represented by $on=\frac{1}{2}(a+b)$, which is the amount of force distributed over one unit of the given plane. Since, further, it was shown that a right shearing stress causes on any plane a stress with an obliquity such that the principal stress bisects the angle between its direction and the normal to the plane, and causes a stress of the same intensity on every plane, we see that $om=\frac{1}{2}(a-b)$ represents, in direction and amount, the force distributed over one unit of the given plane which is due to the right shearing stress.

To find the resultant stress we have only to compound the forces on and om, which give the resultant $or=r$

The obliquity nor is always toward the greater principal stress, which is here assumed to be a.

It is seen that in finding r by this method it is convenient to describe one circle about o with a radius $of=\frac{1}{2}(a+b)$ and another with a radius $og=\frac{1}{2}(a-b)$, after which any parallelogram mn can be readily completed. Let nr and mr intersect xx and yy in hk and ij respectively; then we have the equations of angles,

$$noh=nho=\tfrac{1}{2}kno,\ nok=nko=\tfrac{1}{2}hno,$$
$$moi=mio=\tfrac{1}{2}jmo,\ moj=mjo=\tfrac{1}{2}imo,$$

hence $hn=kn=on=\frac{1}{2}(a+b)$

$$\therefore hk=a+b,$$

and $rk=rj=a$, $rh=ri=b$.

It is well known that a fixed point r on a line of constant length as $hk=a+b$, or $ij=a-b$ describes an ellipse, and such an arrangement is called a trammel. If x and y are the coordinates of the point r, it is evident from the figure that $x=a\cos xn$, $y=b\sin xn$, in which xn signifies the angle between xx and the normal on.

$\therefore \frac{x^2}{a^2}+\frac{y^2}{b^2}=1$ is the equation of the stress ellipse which is the locus of r; and xn is then the eccentric angle of r. Also, since $noh=nho$, $nb'r=nrb'$; hence $b'r \parallel xx$ and $a'r \parallel yy$ determine r.

In this method of finding r it is convenient to describe circles about o with radii a and b, and from a' and b' where the normal of the given plane intersects them find r.

We shall continue to use the notation employed in this problem, so far as applicable, so that future constructions may be readily compared with this. It will be convenient to speak of the angle xon as xn, nor as nr, etc.

PROBLEM 2.—When a state of stress is defined by principal stresses of unequal intensity and unlike sign, *i.e.* in a state of oblique shearing stress, to find the intensity and obliquity of the stress at o on any assumed plane having the direction uv.

In Fig. 8 the construction is effected according to both the methods detailed in problem 1, and it will be at once apprehended from the identity of notation.

Since a and b are of unlike signs $a+b=on$ is numerically less than $a-b=a'b'$.

The results of these two problems are expressed algebraically thus:

$$r^2=\tfrac{1}{4}(a+b)^2+\tfrac{1}{4}(a-b)^2+\tfrac{1}{2}(a^2-b^2)\cos 2xn$$
$$\therefore r^2=\tfrac{1}{2}[a^2+b^2+(a^2-b^2)\cos 2xn]$$
$$\text{or, } r^2=a^2\cos^2 xn+b^2\sin^2 xn.$$

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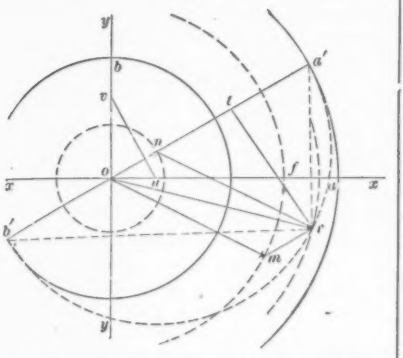
FIG. 8.



If r be resolved into its normal and tangential components $ot=n$ and $rt=t$

then, $n=\frac{1}{2}[a+b+(a-b)\cos 2xn]$,

or, $n=a\cos^2 xn+b\sin^2 xn$,

and,

$t=\frac{1}{2}(a-b)\sin 2xn=(a-b)\sin xn\cos xn$.

It is evident from the value of the normal component n, that the sum of the normal components on any two planes at right angles to each other is the same and its amount is $a+b$: this is also a general property of stress in addition to those previously enumerated.

Also $$\tan nr=\frac{t}{n}=\frac{a-b}{a\cot xn+b\tan xn}$$

The obliquity nr can also be found from the proportion

$$\sin nr : \tfrac{1}{2}(a-b) : : \sin 2xn : r.$$

In the case of fluid stress the equations reduce to the more simple forms:

$$a=b=r=n,\ t=0$$

For right shearing stress they are:

$$a=-b=\pm r,\ n=\pm a\cos rn,$$
$$t=\pm a\sin rn,\qquad rn=2\,xn.$$

And for simple stress they become:

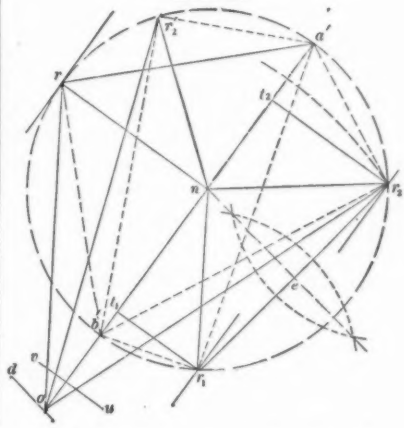
$$b=0,\ r=a\cos rn,\ n=a\cos.^2 rn,$$
$$t=a\sin rn\cos rn,\ rn=xn.$$

PROBLEM 3.—In any state of stress defined by its principal stresses, a and b, to find the obliquity and plane of action of the stress having a given intensity r intermediate between the intensities of the principal stresses.

To find the obliquity nr and the direction uv let Fig. 7 or 8 be constructed as follows: assume the direction uv and its normal on, and proceed to determine the position of the principal axes with respect to it. Lay off $oa'=a$, $ob'=b$, in the same direction if the intensities are of like sign, in opposite directions if unlike. Bisect $a'b'$ at n and on $a'b'$ as a diameter draw the circle $a'rb'$. Also, about o as a center and with a radius $or=r$ draw a circle intersecting that previously drawn at r; then is nr the required obliquity; and $xx \parallel b'r$, $yy \parallel a'r$ are the directions of the principal stresses with respect to the normal on.

PROBLEM 4.—In a state of stress defined by two given obliquities and intensities, to find the principal stresses, and the relative position of their planes of action to each other and to the principal stresses.

FIG. 9.



In Fig. 9 let nr_1, nr_2 be the given obliquities measured from the same normal on, and $or_1=r_1$, $or_2=r_2$ the given intensities. As represented in the figure these intensities are of the same sign, but should they have different signs, it will be necessary to measure one of them from o in the opposite direction, for a change of sign is equivalent to increasing the obliquity by 180°, as was previously shown.

Join r_1r_2 and bisect it by a perpendicular which intersects the common normal at n. About n describe a circle $r_1r_2a'b'$; then $oa'=a$, $ob'=b$, $a'r_1$, $b'r_1$,

are the directions of the principal stresses with respect to r_1 and $b'r_2$, $a'r_2$ with respect to r_2, *i.e.*, $ob'r_1 = xn_1$ and $ob'r_2 = xn_2$

$$\therefore\ n_1n_2 = ob'r_2 - ob'r_1 = r_2b'r_1 = r_2a'r_1$$

In case the given obliquities are of opposite sign, as they must be in conjugate stresses, for example, it is of no consequence in so far as obtaining principal stresses a and b is concerned whether these given obliquities are constructed on the same of on, or on opposite sides of it; for a point on the opposite side of on as r_2' and symmetrically situated with respect to r_2 must lie on the same circle about n. But in case opposite obliquities are on the same side of on we have $n_1n_2 = ob'r_1 + ob'r_2 = r_1b'r_2'$.

It is unnecessary to enter into the proof of the preceding construction as its correctness is sufficiently evident from preceding problems.

The algebraic relationships may be written as follows.

$$\tfrac{1}{4}(a-b)^2 = \tfrac{1}{4}(a+b)^2 + r_1^2 - r_1(a+b)\cos n_1r_1$$

$$\tfrac{1}{4}(a-b)^2 = \tfrac{1}{4}(a+b) + r_2^2 - r^2(a+b)\cos n_2r_2$$

$$\therefore\ (a+b)(r_1\cos n_1r_1 - r_2\cos n_2r_2) = r_1^2 - r_2^2$$

Also $(a-b)\cos 2xn_1 + a + b = 2r_1\cos n_1r_1$

$(a-b)\cos 2xn_2 + a + b = 2r_2\cos n_2r_2$

which last equations express twice the respective normal components, and from them the values of xn_1 and xn_2 can be computed.

Problem 5.—If the state of stress be defined by giving the intensity and obliquity of the stress on one plane, and its inclination to the principal stresses, and also the intensity of the stress on a second plane and its inclination to the principal stresses, to find the obliquity of the stress on the second plane, and the magnitude of the principal stresses.

Let the construction in Fig. 9 be effected thus: from the common normal on lay off or, to represent the obliquity and intensity of the stress on the first plane; draw od so that $nod = xn_2 - xn_1$ the difference of the given inclinations of the normals of the two planes; through r_1 draw r_1r_2 perpendicular to od; about o as a center describe a circle with radius r_2 the given intensity on the second plane, and let it intersect r_1r_2 at r_2 or r_2', then is nr_2 the required obliquity. This is evident, because

$$xn_1 = nb'r_1 = \tfrac{1}{2}a'nr_1,\ xn_2 = nb'r_2 = \tfrac{1}{2}a'nr_2,$$

$$\therefore\ nod = one = \tfrac{1}{2}(onr_1 + onr_2) = 180^\circ - (xn_2 - xn_1)$$

If xn_1 and xn_2 are of different sign care must be taken to take their algebraic sum.

The construction is completed as in problem 4.

Problem 6.—In a state of stress defined by two given obliquities and either both of the normal components or both of the tangential components of the intensities, to find the principal stresses and the relative position of the two planes of action.

If the obliquities nr_1, nr_2, and the normal components $ot_1 = n_1$, $ot_2 = n_2$ are given, draw perpendiculars at t_1 and t_2 intersecting or_1 and or_2 at r_1 and r_2 respectively.

If the tangential components $t_1r_1 = t_1$ and $t_2r_2 = t_2$ are given instead of the normal components, draw at these distances parallels to on which intersect or_1 or_2 at r_1r_2 respectively. Complete the construction in the same manner as before.

Problem 7.—In a state of stress defined by its principal stresses a and b, to find the positions and obliquities of the stresses on two planes at right angles to each other whose stresses have a given tangential component t.

Fig. 9, slightly changed, will admit of the required construction as follows: lay off on the same normal on, $oa' = a$, $ob' = b$; bisect $a'b'$ at n; erect a perpendicular $ne = t$ to $a'b'$ at n; draw through e a parallel r_1r_2 to on intersecting or_1 and or_2 at r_1 and r_2 respectively. Then the stresses $or_1 = r_1$, $or_2 = r_2$ have equal tangential components, and as previously shown these belong to planes at right angles to each other provided these tangential components are of opposite sign. So that when we find the position of the planes of action one obliquity, as nr_2, must be taken on the other side of on, as nr_2'. The rest of the construction is the same as that already given.

Problem 8.—In a state of stress defined by its principal stresses, to find the intensities, obliquities and planes of action of the stresses which have maximum tangential components.

In Fig. 9 make $oa'=a$, $ob'=b$ and describe a circle on $a'b'$ as a diameter; then the maximum tangential component is evidently found by drawing a tangent at r parallel to on, in which case $t=a-b$, and rb', ra' the directions of the principal stresses make angles of 45° with on, which may be otherwise stated by saying that the planes of maximum tangential stress bisect the angles between the principal stresses; or conversely the principal stresses bisect the angles between the pair of planes at right angles to each other on which the tangential stress is a maximum.

It is unnecessary to extend further the list of problems involving the relations just employed as they will be readily solved by the reader.

In particular, a given tangential and normal component may replace a given intensity and obliquity on any plane.

We shall now give a few problems which exhibit specially the distinction between states of stress defined by principal stresses of like sign and by principal stresses of unlike sign, (*i.e.* the distinction between oblique stress and oblique shearing stress).

PROBLEM 9.—In a state of stress defined by like principal stresses, to find the inclination of the planes on which the obliquity of the stress is a maximum, to find this maximum obliquity and the intensity.

In Fig. 10 let $oa'=a$, $ob'=b$ the principal stresses; on $a'b'$ as a diameter describe a circle; to it draw the tangent or_0; then nr_0 is the required maximum obliquity and or_0 the required intensity. It is evident from inspection that in the given state of stress there can be no greater obliquity than nr_0. The directions of the principal axes are $b'r_0$, $a'r_0$ as has been before shown.

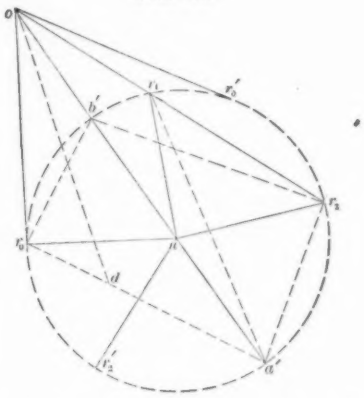
There are two planes of maximum obliquity, and or_0' represents the second; they are situated symmetrically about the principal axes.

Bisect nr_0 by the line od, then

$$oa'r_0=yn \therefore onr_0=2yn, \text{ but}$$
$$onr_0+nor_0=90° \text{ or, } 2yn+nr_0=90°$$
$$\therefore \tfrac{1}{2}nr+yn=45°, \text{ but}$$
$$odr_0=doa'+oa'd \therefore odr_0=45°,$$

hence the line bisecting the angle of maximum obliquity bisects also the angle between the principal axes. This is the best test for the correctness of the final position of the planes of maximum obliquity with reference to the principal axes.

FIG. 10.



PROBLEM 10.—In a state of stress defined by its maximum obliquity and the intensity at that obliquity, to find the principal stresses.

In Fig. 10 measure the obliquity nr_0 from the normal on and at the extremity of $or_0=r_0$ erect a perpendicular intersecting the normal at n. Then complete the figure as before. The principal axes make angles of 45° at o with od which bisect the obliquity nr.

The algebraic statement of Problems 9 and 10 is:

$$\sin nr_0=\frac{a-b}{a+b}=-\cos 2xn,\ r_0^2=ab.$$

$$r_0=a\cot xn=b\tan xn \quad \therefore a=b\tan^2 xn$$

The normal and tangential components are:

$$n_0=\frac{2r_0^2}{a+b}, \qquad t_0=\frac{r_0(a-b)}{a+b}$$

PROBLEM 11.—When the state of stress is defined by like principal stresses, to find the planes of action and intensities of a pair of conjugate stresses having a given common obliquity less than the maximum.

In Fig. 10 let $nr_1=nr_2$ be the given

obliquity; describe a circle on $a'b'$ as a diameter; then $or_1=r_1$, $or_2=r_2$ are the required intensities. The lines $a'r_1$, $b'r_1$ show the directions of the principal axes with respect to or_1, and $a'r'_2$, $b'r'_2$ with respect to $or_2'=or_2$. The obliquities of conjugate stresses are of opposite sign, and for that reason r_2' is employed for finding the position of the principal stresses. The algebraic expression of these results can be obtained at once from those in Problem 4.

PROBLEM 12.—When the state of stress is defined by the intensities and common obliquity of a pair of like conjugate stresses, to find the principal stresses and maximum obliquity.

This is the case of Problem 4, so far as finding the principal stresses is concerned, and the maximum obliquity is then found by Problem 9. The construction is given in Fig. 10.

PROBLEM 13.—Let the maximum obliquity of a state of oblique stress be given, to find the ratio of the intensities of the pair of conjugate stresses having a given obliquity less than the maximum.

In Fig. 10 let nr_0 be the given maximum obliquity, and nr_1 the given obliquity of the conjugate stresses. At any convenient point on or_0, as r_0 erect the perpendicular r_0n, and about n (its point of intersection with on) as a center describe a circle with a radius nr_0 which cuts nr_1 at r_1 and r_2; then $or\div or_2=r_1\div r_2$ is the required ratio.

It must be noticed that the scale on which or_1 and or_2 are measured is unknown, for the magnitude of the principal stresses is unknown although their ratio is $ob'\div oa'$. In order to express these results in formulæ, let r represent either of the conjugate stresses, then as previously seen

$$\tfrac{1}{4}(a-b)^2=\tfrac{1}{4}(a+b)^2+r^2-r(a+b)\cos nr$$

$$\therefore\ 2r=(a+b)\cos.\ nr\pm[(a+b)^2\cos^2 nr-4ab]^{\frac{1}{2}}$$

Call the two values of r, r_1 and r_2; and as previously shown $r_0^2=r_1r_2$; also

$$\cos.\ nr_0=r_0\div\tfrac{1}{2}(a+b)$$

$$\therefore\ \frac{r_1}{r_2}=\frac{\cos nr-(\cos^2 nr-\cos^2 nr_0)^{\frac{1}{2}}}{\cos nr+(\cos^2 nr-\cos^2 nr_0)^{\frac{1}{2}}}$$

When $nr=o$ the ratio becomes

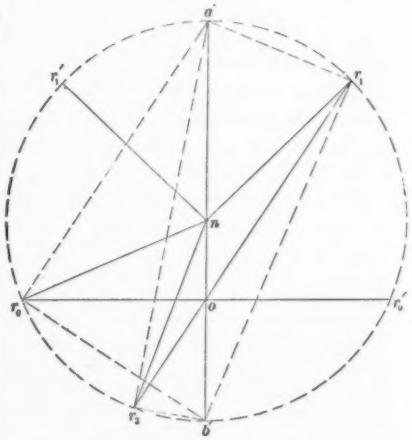
$$\frac{b}{a}=\frac{1-\sin nr_0}{1+\sin.\ nr}$$

PROBLEM 14.—In a state of stress defined by unlike principal stresses, to find the inclination of the planes on which the stress is a shear only and to find its intensity.

In Fig. 11 let $oa'=a$, $ob'=b$, the given principal stresses of unlike sign; on $a'b'$ as a diameter describe a circle; at o erect the perpendicular or_0 cutting the circle at r_0; then is $or_0=r_0$ the required intensity, and $b'r_0$, $a'r_0$ are the directions of the principal stresses.

It is evident from inspection that there is no other position of r_0 except r_0' which will cause the stress to reduce to a shear alone. Hence as previously stated the principal stresses bisect the angles between the planes of shear.

FIG. 11.



PROBLEM 15.—In a state of stress defined by the position of its planes of shear and the common intensity of the stress on these planes, to find the principal stresses.

In Fig. 11 let $or_0=r_0$ the common intensity of the shear, and $or_0b'=xn$, $or_0a'=yn$ the given inclinations of a plane of shear; then $oa'=a$ and $ob'=b$ the principal stresses.

The algebraic statement of Problems

14 and 15, when n_0 denotes the normal to a plane of shear, is:

$$\frac{a+b}{a-b} = -\cos.2xn_0,\ r_0^2 = -ab = t_0^2$$

$$r_0 = \pm a\cot xn_0 = \pm b\tan.xn_0, a = -b\tan^2 xn_0$$

PROBLEM 16.—When the state of stress is defined by unlike principal stresses, to find the planes of action and intensities of a pair of conjugate stresses having any given obliquity.

In Fig. 11 let nr_1 be the common obliquity, $oa' = a$, $ob' = b$ the given principal stresses. On $a'b'$ as a diameter, describe a circle cutting or_1 at r_1 and r_2; then $or_1 = r_1$, $or_2 = r_2$ are the required intensities. Also, since the obliquities of conjugate stresses are of unlike sign, the lines $r_1'a'$, $r_1'b'$ show the directions of the principal stresses with respect to on_1, and r_2a', r_2b' with respect to on_2.

PROBLEM 17.—When the state of stress is defined by the intensities and common obliquities of unlike conjugate stresses, to find the principal stresses and planes of shear.

In finding the principal stresses this problem is constructed as a case of Problem 4, and then the planes of shear are found by Problem 14. The construction is given in Fig. 11.

PROBLEM 18.—Let the position of the planes of shear be given in a state of oblique shearing stress, to find the ratio of the intensities of a pair of conjugate stresses having any given obliquity.

In Fig. 11 at any convenient point r_0 make $or_0b' = xn$, $or_0a' = yn$ the given angles which fix the position of the planes of shear. On $a'b'$ as a diameter describe a circle; make nr_1 equal to the common obliquity of the conjugate stresses; then is $or_1 \div or_2 = r_1 \div r_2$ the ratio required.

The ratio may be expressed as in Problem 13, and after reducing by the relations

$$r_0^2 = -ab,\ r_0 \div \tfrac{1}{2}(a+b) = -\tan.2xn,$$

we have,

$$\frac{r_1}{r_2} = \frac{\cos nr + (\cos^2 nr + \tan^2 2xn_0)^{\frac{1}{2}}}{\cos nr - (\cos^2 nr + \tan^2 2xn_0)^{\frac{1}{2}}}$$

When $nr = o$ the ratio becomes

$$-\frac{a}{b} = \frac{1+\cos 2xn_0}{1-\cos 2xn_0}$$

STREET-CLEANSING IN PARIS.

By M. VAISSIERE.

From "Annales des Ponts et Chaussées," Abstracts published for the Institution of Civil Engineers.

THE cleansing of the public thoroughfares in Paris, formerly undertaken by the Prefect of Police, is now a function of the Prefect of the Seine. The staff consists of two chief engineers, one for each group of arrondissements, one group being sub-divided into three sections, each under the charge of an executive engineer; and the other into five sections, similarly supervised. These sectional engineers have under them fifty-one superintendents and sixty-one overseers, whose employment imposes upon the municipal budget an annual cost of 260,000 francs. The scavenging plant is kept in a central depot, where materials of every description are stored and classified for ordinary and extraordinary service, when snow and ice render additional assistants necessary.

The depots contain supplies of chloride of lime, sulphate of zinc, sulphate of iron, and carbolic acid, as disinfectants; and hydrochloric acid nitro-benzide (acide de mirbane), as cleansing agents. The chloride of lime, of a strength of 100° to 105°, is successfully employed for the disinfecting of places tainted with urine or fæcal matter, also for the cleansing of gutters carrying sewage water. Sulphate of iron and sulphate of zinc are both used under the same conditions. Sulphate of iron possesses the disadvantage of rusting objects to which it is applied. Sulphate of zinc is stronger in its action, but costs a little more. It pro-

duces no smell, nor does it leave any trace. It is much employed in summer for washing and watering the basements of the Halles Centrales, used for fish, poultry, and offal. At a strength of $\frac{1}{8}$, and mixed with three per cent. of sulphate of copper, sulphate of zinc makes a good disinfecting liquor, which preserves its qualities a long time and is of great use in private houses. Carbolic acid is not strictly speaking, a disinfectant; it does not act like chloride on putrid matter, but arrests and prevents fermentation, doubtless by destroying the spores. It is therefore always employed when it is desired to destroy the germs of putrid fermentation. It is used at a strength of about $\frac{1}{10}$, say a gallon of the acid to forty gallons of water. At strengths of $\frac{1}{100}$ and $\frac{1}{200}$ it gives good results for watering once or twice a week in summer those parts of the Halles Centrales liable to infection. It is even used as low as $\frac{1}{1000}$ for watering streets and gutters. Hydrochloric acid is applied to urinals and slaughter-houses. In places much encrusted with tartar it is used at a strength of $\frac{1}{5}$. Lowered to $\frac{1}{10}$ it cleans smooth walls and flags sufficiently. In ordinary rinsings a strength of $\frac{1}{15}$ suffices. It leaves a disagreeable odor behind, which is however quickly dissipated. Mirbanic acid (nitro-benzide) is more energetic than the foregoing, but it produces a disagreeable smell of bitter almonds, and leaves a white film which has to be washed off. It is used at the same strengths as hydrochloric acid. The annual cost for plant and disinfecting materials of all descriptions is £8,800 (220,000 francs).

The engineers of the city of Paris are also charged with the sweeping of the roads, an area of 12,916,800 square yards being cleaned between 3 and 6 A.M. in summer and between 4 and 7 in winter. The carts for removing the public and private refuse work from 6 to 8 A.M. in summer and from 7 to 9 in the winter. The filling of each cart is attended to by the driver aided by two shovellers, the latter having to provide during the rest of the day supplemental sweepings wherever required, to rinse the gutters twice a day, and to clear and disinfect urinals, &c. These matters are ordinarily finished by 4 o'clock in the afternoon, except in unfavorable weather. The engineers have all at their disposal a staff of

	fr. c.	fr. c.
2,200 men at from	2 50 to 4	0 per day.
950 women "	0 20 to 0	25 per day.
30 children (boys) at	0 20	per hour.

In addition there are one hundred and ninety mechanical sweepers, and as each machine represents the effective work of ten men, the total scavenging staff may be considered as composed of nearly five thousand laborers.

The mechanical sweepers which, after numerous trials and much hesitation, have been introduced into Paris are, the English machine, improved by M. Sohy, and the machine of M. Blot, the former being preferred. The mechanism of both is simple, works with regularity, and occupies little space; it consists of a frame-work upon two wheels with a seat for the driver. At the back is placed the sweeping apparatus, composed of an inclined circular bass broom, actuated by gearing driven from one of the wheels of the carriage. By means of a clutch the driver can from his seat easily put the broom in or out of gear. The machine is employed in all weathers, and works as well on paved roads as upon macadam or asphalt. Each machine weighs rather over 14 cwt., and can be drawn by one horse. It sweeps about 6,578 square yards per hour. The cost of a machine is £40, and its annual maintenance, exclusive of renewals of the brush, £8. The cost of a new brush is about £2 16s. (70 francs), which will work for from one hundred and sixty to one hundred and eighty hours.

The Paris mud no longer possesses the manurial strength of former times, and in consequence the receipts derived by the municipality from this source have greatly diminished. It is at present disposed of by public tender to responsible contractors for terms of about four years. For its removal there are daily employed five hundred and twenty carts, and nine hundred and eighty horses. The average bulk removed per day is about 2,223 cubic yards (1,700 cubic meters).

When a fall of snow occurs, attention is first directed to clearing the footpaths and crossings, so as to insure uninter-

rupted circulation of foot-passengers. The town scavengers sand the roads wherever it is necessary for the carriage traffic. At the same time numerous auxiliaries are organized to remove the snow from the principal thoroughfares, in the order of their relative importance. For removing the snow the General Omnibus Company are bound by their concession to furnish fifty wagons, and carts are specially arranged for with the providers of sand and gravel at the beginning of winter, the contractors for maintaining the public roads being also bound to hold their carts at the disposition of the sectional engineers. In certain cases the half-melted snow is swept into the sewers, especially those carrying warm water. Melting by steam has been tried, when a continuous jet was introduced into a mass of banked snow, but it melted very slowly at first, and the melting ceased after the cavity had increased to a certain size. Two descriptions of snow plough are kept in store, one for manual, the other for horse power; but they have never been used, as the coating of snow seldom attains sufficient thickness, and as it is too quickly compressed and hardened by the traffic. As a rule the sum allowed in the budget, about £7,000, suffices for the extra labor incurred; but occasionally severe winters cause this to be greatly exceeded, as in 1875–76, when the increase amounted to £8,000.

Both hose and carts are used for watering the thoroughfares, the former for the boulevards, the avenues, and a certain number of first-class streets. The watering plant belongs to the municipality. Three descriptions of carts are in use, two heavy wooden ones are now being superseded by the third, Sohy's cart, made of sheet iron. The carts contain 220, 242, 286 gallons respectively, and will water from 2,400 to 3,350 square yards. The watering by hose is attended to by the ordinary street cleaners, who can easily water 24,000 square yards in thirty-five minutes, deducting the time necessary to connect the apparatus with the mains. There are three hundred and twenty-two water carts, which on the average disperse 1,311,200 gallons of water over a surface of 7,139,163 square yards. A surface of 2,783,092 square yards is watered by hose, and this system is being greatly developed on account of its convenience and cheapness. The annual cost of watering is £18,000.

IRON AND STEEL FOR SHIPBUILDING, &c.

By W. W. KIDDLE, A. I. C. E.

From "Nautical Magazine."

It is a common saying that we live in an age of progress, yet it may well be doubted if advantage is fully taken of all the great resources which nature has pre-eminently conferred on Great Britain. Not long since the whole country was drifting into a self-complacency which has severely injured trade, by unsettling the minds of the majority of the working classes as to the nature of the principles which govern it. They appeared to think that when prices were forced up by combination to an unnatural level the results were to stand forever. But the rude shocks of competition and its consequent results, have awakened Englishmen to the fact that other countries can successfully mine the coal, and smelt the iron, and make huge castings, and ply the loom, to an extent which at one time seemed impossible. In defiance of what trade delegates may hold forth or workmen affect to believe, foreign manufactures are gradually supplanting many which at one time appeared to have exclusively taken root in English soil. Many great political economists also affect to see no danger to our mercantile supremacy in this flooding of the markets of the world with the produce of our rivals, and speak of the absence of capital as an insurmountable barrier to their progress. Capital is the child of labor, and where there are willing hands and

good security it will find a resting place and fructify, as it ever does, under such favorable circumstances; while, like the sensitive plant of Central America, it instinctively closes up at the approach of danger. Holland has created capital out of the sand dunes of the German Ocean, the beds of morasses, and even the bottom of her lakes, until individually she is one of the richest countries in Europe. With such evidence, can there be a doubt of the ability of more favored nations to follow a similar path. At no remote period a foreign flag was not often seen in any of the great commercial ports of India, China, or the West Indies; yet at this moment they have nearly the whole of the heavy goods trade, and no inconsiderable portion of more valued freights. The steam fleets of Hamburgh and Bremen may now be met in America and the Spanish Main, bidding for freights which were formerly carried exclusively in English bottoms. One of the great staples—tobacco—is almost monopolized by a German line. We all remember the witticisms which were launched against the first attempts of Germany to become a Naval power. *Punch* is silent now, and finds other subjects for caricaturing. It would add to his fame if he were wiser in his conceits, for the perseverance of a race which is not to be daunted by failure, has already made its mark on an element upon which Englishmen, until recent times, imagined they had no rivals. This has been accomplished under disadvantages which might well have made a more favorably placed people pause, as their limited coast in the bight of the North Sea is full of shoals, is low, is destitute of good harbors, and is on a dead leeshore, with all the prevailing winds. At one time no undertaking ever offered a less chance of success. It is now completed—ships, crews, and harbors—and in a few years the new creation will become an important factor in European complications. Such a result proves that modern science, backed by an indomitable will, can dispense with accumulations of capital until it can be exacted from conquered states, a proceeding which the plundered will neither forget nor forgive. The most fatal weakness which can come over individuals or nations is the undervaluing of an enemy, and it is one from which England has suffered in a pre-eminent degree in recent times. It caused the loss of the thirteen colonies, the capture or destruction of several men-of-war on a subsequent occasion, the Indian Mutiny, and many other disasters of a similar nature. May she take warning from the past and regulate her conduct accordingly in the future.

In arts and manufactures the same indifference has begotten competition, which has seriously affected the staple industries of the country, and it is to be regretted that a large portion of the injury has arisen from causes which the merchant princes of the last generation would have scorned to entertain. The Hindoo, after washing his highly-sized cloth in the waters of the Ganges, does not recognize it as the same material which a few minutes before was apparently thick and glossy. The African, as he looks at his shattered hand and broken gun-barrel, or, when face to face with the wild beasts of the forest, finds his powder will not send a bullet into the head of the elephant or the buffalo, curses the dishonest trader to whose rapacity he may probably owe the loss of his limbs or his life. If enormous capital be absolutely necessary before commercial enterprises can succeed, how comes it to pass that America can produce rifles and send them to Constantinople at a price which this country cannot compete with? How comes it to pass that the artillery of the great armies on the Continent and the heavy rifled guns on the shores of the Bosphorus, the Baltic, and the Mediterranean should be the work of German forges, while not a single order has reached this country since the commencement of the Russo-Turkish war? It would be idle to say that this arose from a regard of the neutrality laws, or even from a higher principle; the love of gain rises superior to either. How comes it to pass that the locomotives from the factories of the United States are scaling the Andes, or running on the plains of Peru, when the roads on which they ply are the offspring of English capital? How comes it to pass that the iron castings and bar iron of Belgium are constantly finding their way into the seats of English trade, and underselling rivals on their chosen ground? Instances might be multiplied

but there are unmistakeable indications that every year the struggle for the custom of the world will become more intense, and the results more uncertain, unless the masters and working men of England resolve to work together and redeem a prestige which has been rudely shaken by recent events.

To aid this great work, the genius of the engineer is absolutely necessary, in order to more fully develop the hidden powers which nature only yields to patient research, and to make them serviceable to the uses of man. For centuries the great work has been slowly progressing, but artificial wants have, during recent years, increased to such an extent as to imply that the time has arrived for the advent of one of those great inventions or improvements which mark an age.

For some time the consumption of fuel per horse-power has not sensibly decreased and men have anxiously watched the numerous experiments which have been tried, with feelings akin to those who are aware that the advantages with which they commenced life are slipping from their grasp. To regain that ascendency another start is necessary, and when patient research has developed the means by which one pound of coal will do double its present amount of work, we shall enter on a new phase of prosperity. For the want of this factor, foreign merchant navies have long been gaining on the English as before described. When it is discovered, the cheaply worked sailing ship of the Northmen will disappear as surely as the once famed and much vaunted American liner has before the Cunard and the Inman steamers.

At present, economy in manning and equipment of steam vessels is carried, in many instances, beyond the limits of prudence and safety, therefore retrenchment cannot be made under those headings. Indeed, it is highly probable that the State or the great insurance corporations will, before many years have elapsed, step in and demand legislation on the subject, for life and property alike appear to suffer from its omission, notably in the grain and coasting trades. A steam ship of 1041 tons, recently wrecked, had a crew of deck hands amounting to four all told. In other words, one seaman, one ordinary to work the winches, the carpenter, and a boy. This is an extreme, although not an exceptional case, but it goes to prove that the most elaborate machinery cannot economize any more in that quarter. The only hope of a further reduction of expense now depends on scientific discoveries which may be utilized by practical men, until the whole carrying trade of the country owes its transport to the agency of mechanical power. The days of propulsion by sail can never again be highly remunerative around the shores of the United Kingdom. Men may lament the decay of ancient seamanship, but cannot change the inevitable. They may with equal reason regret the extinction of the Knights of Malta.

It appears singular that with iron in unlimited quantities in so many of the counties in England, so little comparative progress is made to utilize it. In this particular we are far behind the United States, although their command of every species of timber for building purposes is far in advance of that of the United Kingdom. In all the principal cities and towns the rafters, the shop fronts, and fittings of every description are cast or wrought iron, notwithstanding the expense is far greater than what it would be in England. From this fact it is reasonable to assume that architects still love to cling to old traditions in lieu of entering on a new field. If by any mode of reasoning they could be induced to adopt the American system, the impulse it would give to the workers in iron cannot be estimated, and this without injuring existing trades. Whatever may be advanced to the contrary, as matters of fact the introduction of railways increased the value of horses, the introduction of iron shipbuilding, the wages of shipwrights, and the more universal adoption of iron in the building of houses would, in all probability, ultimately increase the earnings of joiners and house carpenters, by introducing improvements of style which need not be dwelt on here. However, the inexorable laws of supply and demand will assuredly force iron into more general use, for year by year the supply of convertible timber is growing less, and a forest which has been once felled is seldom replaced. If it were, at least two generations must elapse before it reached

maturity. From this serious drawback iron is wholly exempt, requiring but the skill of the miner and the smelter to raise it in unlimited quantities. In no other country up to the present time has the precious metal been found in such workable sites, or so near to the fuel which is required for extracting it. Vast as the mines may be which are opened up in the United States, their locality is generally remote from the great arteries and centers of commerce, thus rendering the cost of transport a serious item before reaching the market. Under anything like equal circumstances, this will long be a drawback on the energetic race across the Atlantic; so much so, that however they may strive to rival England in foreign markets, nothing short of misunderstanding and strikes in this country can give them a chance of success. Unfortunately, they have been of such constant occurrence during recent years as to damp the spirits of those enterprising men to whom the world is so deeply indebted. It is not going beyond the limits of probability to state that if the time which has been lost during strikes in the shipbuilding trades alone could be regained, the labor would complete a coasting fleet of iron steamers which might not only have tended to equalize the price of heavy goods throughout the United Kingdom, and to increase our foreign trade by enabling coals to be carried more cheaply to the Continent, but what is of more importance still, would also tend greatly to reduce the death roll of the maritime population. Unfortunately, a lamentable ignorance of the principles of political economy on the part of the leaders of trades' unions has prevented this, and the seeds of distrust between employer and workmen have been so industriously sown, that the two classes stand like rivals, possessing no common interests.

Commerce has been likened to a hardy plant which thrives best when untrammelled with artificial help. When the great political economist penned the lines, strikes and lock-outs were unknown; and when contracts were entered into there was a chance of carrying them to a successful issue on the basis of the original calculation. All this has been changed; and it is not long since the iron workers of all denominations on the Clyde remained out six months on strike, in the vain effort to force wages beyond the limits, which would not only debar the masters from receiving renumeration for the science and capital employed, but likewise involve them in heavy pecuniary loss. A few years since, £20 per ton could be demanded for the construction of a first-class iron ship, which now may be had for £12. Yet, under the leadership of designing or misguided men, the workmen essayed to dictate unbearable terms to their masters. They failed, as wrong always must, in the end; and the loss which has arisen to all concerned cannot be reckoned by the amount of wages and unemployed capital, but by the distrust it has engendered at home, and the encouragement it has given to rivals abroad. America, hoping that a recurrence of such catastrophes will ultimately drive a large portion of iron shipbuilding to her shores, has already relaxed in its favor the terms of that almost prohibitive tariff on iron and steel, and in future all materials used in the construction of ships are to be admitted free of duty. This is undoubtedly the first step towards a rivalry, which at no distant period may become formidable, especially if great lines of native steamships are ultimately established between the West Coast of America and China and Japan. English-built vessels now monopolize the lion's share of this lucrative traffic; but Americans are not slow to copy what is really useful.

Mr. Brassey touched on dangerous ground when, at a recent lecture, he announced that the peculiarly-trained touch of the English artizan made him superior to any in the world. There are grave reasons for believing that, when circumstances call it forth, the hands of our Transatlantic brethren will in nowise be less cunning than those of our own. Up to recent times they have had no inducements to finish their work in a style similar to that of this country; yet in many species of tools and agricultural machinery they already take the lead. Even the thoughful and highly-educated German acknowledges this superiority, and is calling on his Government to more heavily weight the imports of the ingenious and self-reliant inhabitant of the New World. It is one of the triumphs of the engineer that his genius

has enabled this almost impossible innovation to be accomplished—an innovation which the most far-seeing men of the last generation could not have anticipated.

Shipbuilders appear to use iron more extensively than the members of any other profession. In none has it been of such vital importance to the welfare of the country, and its introduction was most opportune. The woods best adapted for the purpose of the naval architect had become scarce not only in England and the Continent, but in foreign countries. The African and Indian forests had been felled in almost every accessible locality on the banks of the great rivers and estuaries, and that which still remained inland failed to be of service for the lack of transport. Statesmen were talking of interdicting the felling of oaks, except for the construction of ships of war, when the substitution of an inexhaustible material set the question at rest for ever; and the grand old trees, no inapt representatives of the race who dwell around them, have been spared to adorn the landscape around English homes.

A movement has recently been inaugurated for the introduction of steel in lieu of iron for shipbuilding purposes. Of course, if successful, it will form a new starting-point in the art of enabling the merchant to have a vessel twenty or thirty tons per cent. under the present weight—no mean advantage in trades where the carriage of dead weight forms the most remunerative portion of his business. The innovation will have to be conducted with more than ordinary skill and care, from the fact that a rent, which might be of no practical importance in a bridge or a viaduct, might be fatal to a ship. The latter is subjected to strains which test the peculiar qualities of the materials forming the hull in a very marked degree; so much, indeed, that an unusually large factor of safety is adopted by all the great corporations when laying down their rules. Experience and careful study have barely mastered the laws which are necessary to be observed for the safe construction of iron vessels, when new have to be adapted in order that a higher classed metal may be introduced to supply its place. Great difficulties are certain to be met with at the outset. One of these—corrosion—appears to be almost insurmountable, and likely to deter shipowners and shipbuilders from bringing it into extensive use. There are others which, in a practical point of view, will always cause anxiety, such as docking, or lying in the tideway of a rapid river, notably the Mersey, or the Thames, during strong spring floods and gales. The rough knuckles of granite quays on a lee shore require a ship, when docking, to possess other qualities than elasticity and tensile strength, if her sides are to be preserved from bulging, or even fracture. In a similar manner the iron-plated sterns of the Runcorn flats, with their heavy lading of coals, or salt, or iron, would become dangerous to materials lighter than those now in use. Therefore, in making reductions, the laws of stiffness will have to be considered as well as the laws of strength, not only in what has now been mentioned, but in another respect still more important, which the reader will no doubt readily comprehend. The ship being a huge girder, with a top and bottom flange, and a connecting web in the form of topsiders, it is of the utmost importance for the true working of the machinery that all possible rigidity should be given to it. This cannot be secured without a certain thickness of the material employed, for, however great the tensile strength may be, it is only one of the indispensable factors demanded. The stems of the magnificent steamships of the White Star Line, during heavy weather, appear to rise and fall through an arc of eight inches, as measured by an imaginary line, on the break of the forecastle, by an observer close forward. A stronger but more ductile material would probably increase this to a dangerous extent. It is, therefore, evident that great caution and careful experiments will be required before steel can be largely introduced in the plating of the larger class of steamships employed in heavy carrying, and, it may be added, heavy driving trades.

The breadth of lap in their steel plates might probably be increased with advantage in double riveting for stiffening purposes, but not in single, for the caulking of the seam would present greater difficulties in the latter than it now does. It would not be desirable for this reason

to have a greater distance between the edge of the plate and the periphery of the rivet than what is universally allowed by scientific and practical men to be the best for all purposes.

There is still a doubt as to the efficiency of steel rivets, and Her Majesty's ships *Mercury* and *Iris* have been wholly fastened with iron. Under these conditions, the butts being the weakest part of the structure, extra precaution should be taken to make them approximate to the strength of the plates they connect, by an additional row of rivets wherever the strain is great. This plan has in all likelihood been adopted, otherwise the stronger material will more severely test the goodness of the joints than ordinary iron plates would do. For three-fifths of the length amidships, or in broadside ships the whole length of the battery, the butt straps should be treble riveted from the sheer strake to the neutral axis. The general custom now is only to double rivet, with the exception of the sheer strake. Messrs. Harland and Wolff have, in the construction of their ocean steamers, gone far beyond the requirements of any existing regulations on this important point.

In the construction of men-of-war, expense is not so much an object as efficiency, and no difficulties are likely to crop up on questions of finance. But in merchant ships, where economy is one of the primary laws governing the owner and the builder, the cost of an extra row of rivets in a large number of butts becomes of grave importance in times of high priced labor. Subjects of this nature must be left to regulate themselves. It is the profession of the engineer to ascertain what is practicable, and when that is accomplished to leave the monetary details in other hands. His specialty is to make much out of little. Good housekeeping is easy with unlimited means.

The mail steamers on the Atlantic cannot, without serious risk, reduce the thickness of the plates near the waterline owing to the danger of penetration by ice, which, in spring, may not only be found in the neighborhood of the Grand Banks, but in all the great commercial estuaries from the Chesapeake to the shores of Newfoundland. Anderson, in his highly useful manual, says there are no reasons for believing that iron is more brittle in winter than in summer, but qualifies the statement by adding that his experiments were made under cover. It is certain that seamen will not share his opinion, for they have a great dread of the action of intense frost on the plating at the water-line when steaming through an ice-field, especially if it be in hummocks, or greatly denuded by the weather. In this condition, it assumes a lustrous greenish hue, not unlike the tint of the glass which still may occasionally be seen in the cottages of rural districts. At this stage, granite scarcely surpasses it in hardness, and numerous accidents bear out the accuracy of the seaman's reasoning. In the winter of 1874–5, a large percentage of steamers in the North American trades met with serious damage to their bows or propellers, and one, the *Vicksburg*, burst the plates under the counter, and foundered in the vain attempt to back out of the pack. Of course, the theory nursed by seamen may be erroneous, but they are so thoroughly imbued with its correctness, that only practical tests will convince them that their assumption is founded on prejudice. The advocates for steel rivets assert that the defect which exists from burning may be obviated by more care in heating. Whatever may be done within the walls of a foundry, no precautions which can be used in a shipyard will prevent it. Rivet boys cannot be expected to study the temperature when they and the riveters are employed on piecework. Therefore, until steel can be tempered to stand without injury the same rough treatment as iron, there is not much hope of its being generally adopted in the construction of ordinary vessels, except for decktie, stringers, and bulkheads. It is unfortunate that the stiffness as well as the tensile strength of all parts which form a ship are tried in turn. If she grounds on a stony place, irregular bumps severely punish the spaces between the frames, and in some instances, puncture them badly. In a heavy seaway, the decks, sheer strakes, stringers, and bottom, are alternately exposed to tensile and compressive strains, and in docking or loading on a rapid river, the side plating is often tested to the utmost limits of endurance. Take, for an example, a case

of a long steamer entering one of the northern basins on the Liverpool side of the Mersey, which, during north-west gales, have no shelter from the Cheshire shore. But for that peculiar action of the waves known to seamen as the undertow or backwash, it would, at times, be impossible to drop alongside of such formidable walls. Occasionally, a sea rolls over the summit, as it might do in the open, and sends showers of spray to a considerable distance. The danger is in places increased by the want of a bold sweep at the corners, and also by the walls being built perpendicularly in lieu of with a slight curve. No amount of ordinary wear and tear strains and punishes a ship so much as the treatment they sometimes receive from these causes, which certainly might have been avoided when the works were planned. Injuries are often visible in the form of bulged plates, broken rivets, and cracked frames, and when the position of the ship is considered it is not to be marvelled at; she is converted into a huge lever, with the bluff of the bow for a fulcrum, and all abaft it for the long arm, to which may be attached one or more tugs backed by a powerful steam winch to break her round.

Three years since, the writer was requested to examine and report on the construction of a new wharf on the Hudson river, which was intended for the use of the steamers of one of the great mail companies. Through an oversight similar to that pointed out, the corners were badly rounded, and to make this defect more serious, they were lined with deep angle plates from the platform to mean low water level. The probable danger was pointed out to the gentleman who had designed the structure, and a sketch sent to Liverpool to illustrate it. No steps were taken to remedy the evil, one party alleging that it was not their business, and the other that the error, if it was one, should have been pointed out at an earlier date. The result was, that the second steamer which essayed to enter when the freshets were running down, stove in one of her bows, thus causing delay and expense. After the mischief was wrought, the corners were supplemented with circular turret-shaped projections, designed by the writer, and since their erection not the slightest injury has been sustained by any vessel. The American engineer was so much pleased with the simplicity and efficacy of the plan, that he has since announced his intention of adapting it in all docks or jetties, but in lieu of attaching them like patchwork, they will, for the future, form a portion of the permanent piling.

There are good reasons for believing that until experiments have convinced the shipbuilder of the degree to which he may test steel, it will only be largely used in the construction of men-of-war of certain classes, and packets for Channel service. In both, expense is not so much an object as lightness and efficiency, and neither are much subjected to the rude tests of strength which so frequently try the ordinary merchantman. Further, the cargoes of mail packets are seldom heavy, neither is space such an object as to prevent all the important parts of the hull from being made accessible for scaling and painting. Experience demonstrates that when this is carefully carried out, there is practically no limits to the duration of the plate. Whether Nature really holds in her laboratory an antidote to oxidization is uncertain, but we do know that up to the present time the highest chemical science has failed to find one. The greatest scientists have not been rewarded with a glimmer of success, although pretenders of all denominations essay to make the world believe they have solved the great problem. In despair, at the failure of numerous patents, one of the largest steamship companies in Liverpool has recently given orders that common lead paint is now only to be used. In the North Atlantic trade, where ships do not remain long in port, this may stand well, but in tropical seas or foul waters it does not meet the case. A few days of calm weather under the equator, enables animal and vegetable productions to attach themselves to a ship's bottom with marvelous profusion, and when this has commenced there are no means of checking the advance of both.

It will be interesting to note if iron and steel work harmoniously together; under what conditions, if any, wasting will occur to either, and whether the superior tensile strength of one will be in anywise detrimental to the other. It is scarcely possible that the former

occurs, but so many singular combinations take place in Nature, that it will be well to adopt every precaution. The latter is worthy of consideration, from the simple fact that the melting points of iron and steel being different, expansion may cause irregularities in practice which may not readily harmonize. In certain anchorages, chain cables after being submerged a few weeks are deeply scored, so much indeed, that the fiber of the iron stands clearly out, and in places cells resembling the half-section of those of the *teredo navalis* in timber may be traced. Few who have not examined a specimen of the links on the spot, would credit that so much mischief may be done to one of the hardest of materials by some unknown cause. When heaving in, the rust may be taken off like paste. It easily washes away, leaves no trace of weed or shell behind, which almost infers that galvanic action is the cause. Sailors attribute it to an insect, but whatever it may be, the injury arising from the submergence of a few weeks exceeds the ordinary wear and tear of years.

The above statement may be deemed irrelevant to the question. It is simply introduced to show that unexpected causes sometimes throw serious obstacles in the way of great innovations.

THE DRAINAGE SYSTEM OF GLASGOW.

From "The Engineer."

The irrefutable logic of hard facts and dearly-bought experience has completely dispelled the illusion which some time ago prevailed to a very considerable extent, that not merely profits but large fortunes were to be realized by the utilization of sewage. It is now thoroughly well known and acknowledged also, even by those who are somewhat reluctant to make the admission, that raw sewage cannot by any existing process or chemical treatment be converted into an artificial manure which will pay the cost of its own manufacture. A large class persistently refused to give the slightest credence to this view of the question, although it was supported and based upon scientific reports, chemical analyses, and the impartial statements of Royal Commissions, which must have carried full conviction to the mind of any unprejudiced person. It was indeed nothing but the actual loss of the money invested in one or more of the numerous precipitating schemes which finally and conclusively demonstrated to the shareholders the futility of their projects, and the fallacy of their expectations. It has been estimated that one well-known company beguiled the public of a million of money in their fruitless endeavor to effect the desired remunerative conversion. As we proceed with our subject it will be seen that the people of Glasgow are not likely to fall into this error, formerly so prevalent. They appear to be well aware of the specious and illusory nature of the processes, and while recognizing the suitability of the means employed for accomplishing the purification of the effluent water, they entirely discard the idea of attaching any value as a manure to the precipitated sludge. We are inclined to consider that their views in this respect are in the main pretty correct. Towards the close of last year a number of gentlemen were appointed by the Town Council of Glasgow to visit certain large cities and localities in England, to examine into the various systems in operation for the disposal of sewage and refuse matter, and to report upon them accordingly. Manchester, Leeds, Birmingham, our own metropolis, Bradford, Coventry, Croydon, Halifax, and Oldham were all utilized in this way.

The physical situation of Glasgow is similar to that of London, inasmuch as they both possess the great advantage derived from the contiguity of a large tidal river. This offers at once a ready and, in some measure, a natural outlet for the sewage of the riparian city, and so long as the volume of the sewage discharged into it remains comparatively

small, little or no harm is likely to result to the community. But no sooner do these conditions cease to obtain than the health of the inhabitants begins to suffer and the rate of mortality to increase. In order that a river should be maintained in a state of purity it is necessary that some authority should be appointed to take care of it. It certainly does not absolutely follow that the constitution of such an authority will ensure the river being maintained in a pure and unpolluted condition. There is an excellent body called the Thames Conservancy, but if we are to believe the statements of Captain Calver respecting the results of the metropolitan sewage system, the state of the Thames is not such as to reflect much credit upon its Conservators. Notwithstanding this, we entirely concur with the members of the Glasgow deputation, that until a Board of Conservancy is established for the Clyde, as recommended in the report of Sir John Hawkshaw, no works for the discharge of sewage into that river can be undertaken with hope of ultimate success. Contaminated as the Thames unquestionably is by the enormous and continual discharge of sewage into it, it is purity itself in comparison with streams such as the Irwell and the Bradford Beck. It is impossible to expect that rivers and streams similar to those alluded to, which have been permitted to become nothing better than common sewers of the foulest description, can ever be restored to a state of purity until a Conservancy Board is established with powers to deal summarily with all the pulluting parties. The jurisdiction of such a Board, moreover, should not be confined to that portion of a river flowing through any particular town or district, but should embrace the whole drainage area of the basin belonging to it. It is the common, and, at the same time, very just complaint of the inhabitants of many of our large inland towns which are situated on the banks of small rivers, that it is not only a great hardship and expense, but a useless one as well, to compel them to purify their sewage before it is allowed to be discharged into streams which are already rendered as foul as they can possibly be by the filth of other towns.

Although the population of Glasgow is, in round numbers, about one-seventh that of London, yet the sewage of the former town ought not to be permitted to flow into the Clyde without previously undergoing purification. The average range of the tide at Glasgow harbor is only about half that of the Thames at the London Docks, and the average velocity barely exceeds a tenth. Purification of the sewage, either by irrigation or precipitation, before discharging it into the Clyde, is evidently more necessary at Glasgow, where a small range of tide and a feeble current prevail, than at London, notwithstanding the great difference in the relative population. If the sewage is to be purified by irrigation, land must be obtained for the purpose. In other words, an irrigation farm must be established. With regard to this method of dealing with this great sanitary question, the deputation came to the conclusion that "irrigation presents the most perfect means for the disposal and purification of sewage." It was also their opinion, founded upon the actual facts placed before their notice, that under certain favorable circumstances "a sewage farm might be made to yield a profit." The conditions are—the acquisition of land at a reasonable distance from any resident population; the purchase or rental of it at a fair agricultural value; and the distribution of the sewage by the principle of gravitation. The first of these conditions is no doubt advisable, but not absolutely necessary. In spite of several statements respecting the alleged danger to the public health by the establishment of sewage farms, we believe that no reliable evidence has been produced to show that any evil effects have resulted from the existence of such farms, or that the rate of mortality has risen in any town or village in proximity to them. As to the accuracy of their conclusions that a profit might be made, we might say that, up to the present moment, experience tends all the other way.

Of the many ingredients employed for precipitating the solid constituents of sewage, lime appears, in point of general application, to possess advantages over the others. It is cheap, can be readily procured nearly everywhere, and accomplishes the purification of the effluent sufficiently to enable it to be discharged

into any river, the water of which is not used for potable or culinary purposes. The objections against its employment are that its purifying effect is evanescent, and that it produces rather more sludge than some other systems. The first of these objections is merely one of degree; and with regard to the second, it may be observed that when adequate means have to be provided for the removal and disposal of some hundreds of thousands of tons of sludge, a few thousand more or less are not of much consequence, in comparison with the other merits of this particular process. One very ready and convenient plan for disposing of the sludge precipitated from raw sewage is to simply "run it to spoil," that is, to apply it to the making up of, or raising the level of waste and low-lying lands. To such an extent has this system of disposing of the solid contents of privies been for many years carried on in Manchester, that having reference to the large number of houses erected on land made up in this manner, it has been said, "Manchester is a town built upon dunghills." The idea is not by any means a pleasant one, although time and the sanitary influence of natural causes may have removed all noxious and deleterious qualities from the once polluted foundations.

The rate of mortality of any town may be fairly considered as the real test of the efficacy of its sanitary arrangements. An examination of this rate in many of our large towns reveals the very significant fact that the greater the number of water-closets—or, in other words, the greater the use of the water-carriage system—the healthier is the town. London, which is beyond all other cities that in which this method of removing the sewage from habitations is most extensively practiced, returns a rate, calculated on an average of five years, of 22.9. That of Coventry, in which town the number of water-closets is six times that of the privies, is 23.4. It is rather remarkable—although from various circumstances the case is somewhat exceptional—that the rate of mortality is only 19 in Croydon, a place where the water-carriage system is in full operation, and where irrigation is the method employed for utilizing the sewage. In Birmingham, where the rate is 25.2, the water-closets are in the minority; and in Manchester, where the number is comparatively very small, the rate rises to 30.0, and to 29.3 in Salford. Density of population cannot be urged as an independent cause of a high rate of mortality, because in the last two instances quoted, in which the rate is practically identical, the relative densities are as three to one. A comparison between Halifax and the metropolis will also serve to show that there is no necessary connection between these two particulars. The former town has a density of population of only 18 to the acre, with an average death rate of 26.6. The corresponding figures for London are 45.7 and 22.9.

The report of the "deputation" contains some final recommendations with regard to the sanitary measures to be carried out in Glasgow. The majority of these are well known to every engineer and local surveyor, although not always put into execution by the corporations under whom they act. It is recommended that "water-closets in small houses should be discouraged." This would appear to intimate that there should be in Glasgow one system of sewerage for the rich and another for the poor, yet, in a sanitary point of view, there should be no such distinction. Otherwise there is the risk of the water-carriage plan being considered in the light of a luxury to be enjoyed only by the wealthy. Some years ago this, no doubt, was the case. Another of the "recommendations" is to the effect "that the ordinary privies and ashpits be altered to the tub and pail system, to be cleansed daily, as it has been carried out in Manchester." It is a little singular that the deputation should recommend for adoption a plan which, it is said, has earned for the city in question the highest death-rate of all those we have mentioned. The rate of mortality in Glasgow itself is 29.9, so that it can hardly afford to bear any increase.

For the purpose of hardening wood pulleys, the pulley, after it is turned and rubbed smooth, is boiled for about eight minutes in olive oil. It is then allowed to dry, when it will become exceedingly hard.

APPARATUS TO MEASURE DIRECTLY THE STRAIN TO WHICH THE PIECES OF AN IRON LATTICE GIRDER ARE EXPOSED.

By Prof. WILLIAM WATSON, Ph. D., late U. S. Commissioner.

DESCRIPTION; APPLICATION TO A SET OF BARS; EXPERIMENTS ON A LATTICE GIRDER; RESULTS.

In order to ascertain as accurately as possible the amount of the tension, or compression, produced in each of the different iron bars which make up a lattice-girder, the Orleans Railway Company caused numerous experiments to be made upon such a girder, 12 meters long and 1.12 meters high; and the results show that in future a notable economy may be obtained in such girders by a different arrangement of the metal.

DESCRIPTION OF THE APPARATUS.

In order to perceive directly the effect produced upon each bar, to judge of its nature, and to measure exactly its intensity, whether it be extension or compression, M. Dupuy, Chief Engineer, devised the following apparatus; it consists (Fig. 2) of an iron bar pierced at its two extremities, with two holes, A and B, exactly 1 meter apart; this bar is joined at one end with a second bar pierced with three holes, C, D, E, the distances CD and DE being 5 and 100 centimeters respectively, thus forming a bent lever. Two holes, exactly 1 meter apart, are drilled in each bar to be tested, the bent lever is attached to it by the points A and D and the test-load applied. Then as the bar AD lengthens or shortens, the two rods of the bent lever turn around the center C, and as CD is one-twentieth of DE, it follows that the extremity E passes over a space equal to twenty times the amount of expansion or contraction of the bar. A graduated scale serves to measure the space through which the extremity E moves.

The apparatus was first tried by measuring the extension of several iron bars firmly fixed at their upper extremities and supporting a scale-pan, upon which weights were placed. In order to avoid drilling the bars, saddles were screwed very tightly upon them, one of which supported one extremity of the bent lever, and the other the pivot of the index-hand. Also a second system of bent levers, exactly like the first, was placed behind the bar to correct the small errors resulting from torsion.

Three bars were tested, of which the dimensions of the sections were (Plate I) 200 millimeters by 93 millimeters, 270 millimeters by 52 millimeters, and 157 millimeters by 36 millimeters, and the proportional elongations were 0.09 millimeter, 0.18 millimeter, 0.28 millimeter, 0.37 millimeter, under a load of 2, 4, 6, 8 kilograms, respectively. These results agree with those generally adopted, viz., 0.50 millimeter under a load of 10 kilograms per square millimeter of section.

The girder specially constructed for the tests was formed of two flanges united by lattice-bars at 45°. Each flange was formed of two plates, at right angles, held together by two angle-irons. (See Figs. 1 to 5, Plate II). Dimensions of the lattice-bars: First set, 140 millimeters by 9 millimeters; the second set are flanged and are 75 millimeters by 75 millimeters by 10 millimeters.

The top and bottom horizontal plates are 220 millimeters by 20 millimeters; the vertical plates 250 millimeters by 20 millimeters, and the angle-irons 100 millimeters by 100 millimeters by 12 millimeters. Each of these lattice-bars had the measuring-apparatus described above.

The upper and lower flanges of the girder were connected to the walls by jointed iron rods to prevent these flanges from warping, and the testing apparatus was applied at five equi-distant points of the upper, and at five of the lower flange, The girder was then successively subjected to the action of uniformly distributed loads as follows: viz., 5,000, 10,000, 20,000, 30,000, 35,000 and 40,000 kilograms. The results of the last tests, viz.: the observed and the computed stresses upon the diagonals and upon the upper and lower flanges, resulting from a uniformly distributed load of 40,000 kilogrammes are given in Tables I and II.

PLATE I.

Fig. 1.—General elevation.

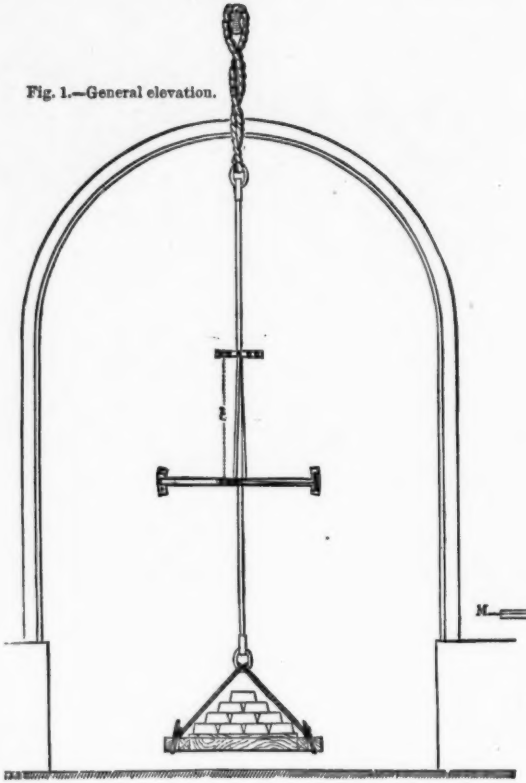


Fig. 2.

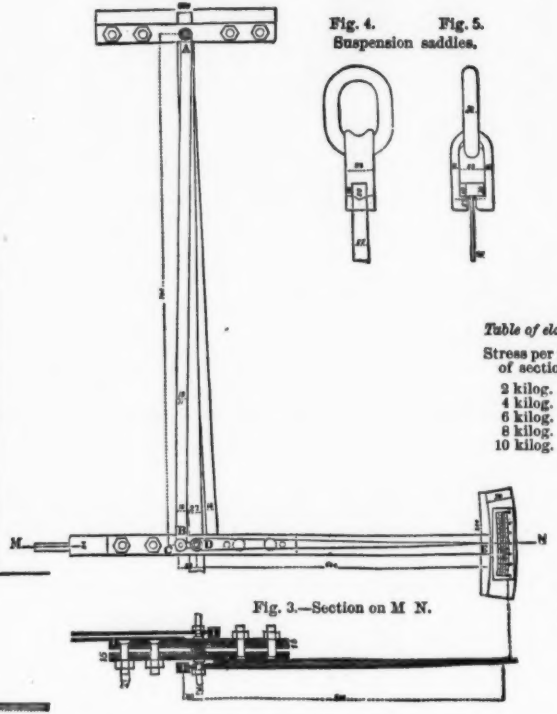


Fig. 3.—Section on M N.

Fig. 4. Fig. 5.
Suspension saddles.

Section of bars tested.
Fig. 6.

Fig. 7.

Fig. 8.

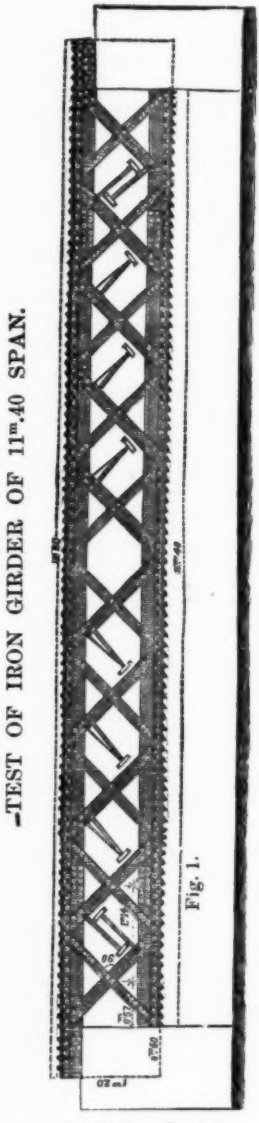
Table of elongation per meter.

Stress per mm. of section.	Elongation.
2 kilog.	0.087 mm.
4 kilog.	0.183 mm.
6 kilog.	0.286 mm.
8 kilog.	0.376 mm.
10 kilog.	0.476 mm.

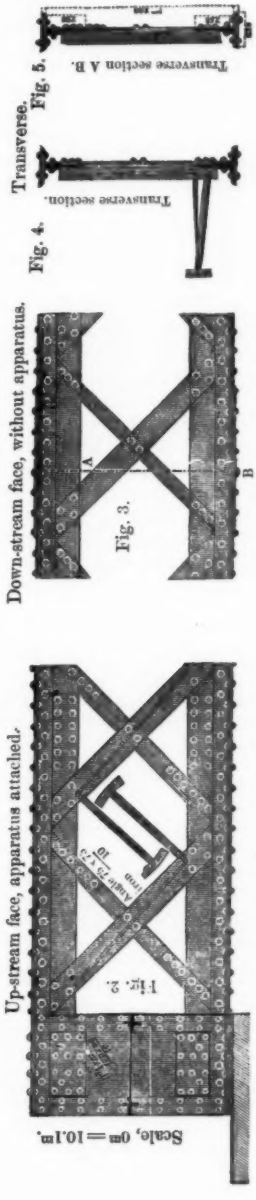
Scales.
Fig. 1 = $\frac{1}{40}$
Figs. 2-8 = $\frac{1}{10}$

APPARATUS TO MEASURE ELONGATIONS OF IRON BARS IN TENSION.

PLATE II.



TEST OF IRON GIRDER OF 11m.40 SPAN.



Transverse.

Table III shows the observed and computed stresses on the diagonals for the case in which a load of 20,000 kilogrammes was concentrated in the middle.

RESULTS.

From tables it appears:

1st. That the stresses on pieces symmetrically placed with respect to the middle of the girder were nearly identical.

2d. That for the uniformly distributed load the flanged diagonals were all compressed.

3d. That the plane diagonals were all extended except those near the middle.

4th. That the stresses on the diagonals diminished in passing from the abutments toward the center.

For the case in which the load of 20,000 kilogs. was concentrated in the middle it appeared that the stresses on the diagonals of the first pannel were about one-half those on the same diagonals for the case of a uniformly distributed load of 40,000 kilograms.

Table II shows the stresses at five equally distant points on each flange, and extending over a length equal to half that of the girder.

In this test the flanges had been weakened near the abutments, a piece of the horizontal plate $3^{m}.30$ long and $0^{m}.010$ thick having been cut away from each extremity, thus reducing each flange, for these portions, to the vertical plate, and two angle irons.

CONCLUSIONS.

The results obtained by these experiments showed that the effects produced upon the lattice-bars were scarcely one-half of those indicated by the common formulæ; and that toward the middle of the girder the bars inclined toward the points of support were extended, while the other set were compressed, which is contrary to the ordinarily received hypothesis. It was also certain that the *rigidity* of the joints of these girders, the parts of which are carefully riveted together, has a considerable influence upon the strength and flexibility of lattice-girders. It is very desirable to measure the real effects which are produced upon the great lattice-girders of bridges already constructed, and this apparatus is well adapted to this purpose.

TESTS OF THE GIRDER.

TABLE I.—LOAD 40000 KILOGS. UNIFORMLY DISTRIBUTED. (Stresses on the Diagonals.)

Nos.	Stresses on the Plane Diagonals		Stresses on the Flanged Diagonals.	
	Observed	Calculated	Observed	Calculated
1	+ 5418	+ 14140	— 5180	— 14140
2	+ 2520	+ 11312	— 5320	— 11312
3	+ 1260	+ 8484	— 420	— 8484
4	+ 882	+ 5656	— 1120	— 5656
5	— 1890	+ 2828	0	— 2828
6	0	+ 2828	— 1386	— 2828
7	— 1400	+ 5656	— 882	— 5656
8	+ 1820	+ 8484	— 1890	— 8484
9	+ 4340	+ 11312	— 3150	— 11312
10	+ 5600	+ 14140	— 5166	— 14140

TABLE II.—LOAD 40000 KILOGS. UNIFORMLY DISTRIBUTED. (Stresses on the Flanges.)

Nos.	* Stresses on the Upper Flange.		Stresses on the Lower Flange.	
	Observed	Calculated	Observed	Calculated
1	—13306	— 21162	+ 4435	+ 21162
2	—36115	— 34699	+29779	+ 37699
3	—34998	— 47375	+32437	+ 47375
4	—44387	— 54118	+37558	+ 54118
5	—51216	— 56338	+42680	+ 56338

TABLE III.—LOAD 20000 KILOGS. CONCENTRATED IN THE MIDDLE.

(Stresses on the Diagonals.)

Nos.	Stresses on the Plane Diagonals.		Stresses on the Flanged Diagonals.	
	Observed	Calculated	Observed	Calculated
1	+ 2394	+ 7070	— 2380	— 7070
2	+ 1512	+ 7070	— 1260	— 7070
3	+ 1386	+ 7070	+ 280	— 7070
4	+ 3654	+ 7070	+ 840	— 7070
5	— 2268	+ 7070	— 980	— 7070
6	— 420	— 7070	+ 2898	+ 7070
7	— 428	— 7070	+ 2520	+ 7070
8	0	— 7070	+ 2520	+ 7070
9	— 700	— 7070	+ 1260	+ 7070
10	— 2100	— 7070	+ 2142	+ 7070

* On five equally distant points extending along one-half the length of the girder.

[In a recent letter to the author, M. Dupuy, says: "This simple apparatus has recently been used to ascertain directly the resistance of the different parts of a bridge—le Pont de Roland, having a span 24.5 meters, consisting of two lattice-girders; the results were very remarkable and have verified the theory held by French engineers, by showing that the riveting of the lattice-bars has the effect of materially diminishing the work done by these pieces. The apparatus should be applied only in those cases in which the pieces to which it is fastened preserve their neutral axis unchanged by the load between the points of attachment and the apparatus."]

An account of the tests of this, and of other bridges by the above apparatus, the results obtained, and the modifications of the present theory of lattice girders which these results seem to require, must be reserved for a subsequent communication.

ON STEAM BOILER EXPLOSIONS, AND EXPERIMENTS IN RELATION THERETO.

By Dr. HERMANN SCHEFFLER.

From "Organ fur die Fortschritte des Eisenbahnwesens," Foreign Abstracts of the Institution of Civil Engineers.

The Author is disposed to refer many boiler explosions to the creation of a marked disproportion between the external pressure acting on the boiler water and its internal temperature. This may act in two ways: (1) as a primary cause of explosion where the taking off of the pressure produces a sudden and violent generation of steam, the shock of which is greater than the boiler can withstand; (2) as a secondary cause where a rent in the boiler produced by some other means creates the disproportion, and the ensuing generation of steam comes in to render the explosion much more violent and destructive. The second fact is generally admitted, but as to the former there are great differences of opinion, and it is therefore desirable that the point should be cleared up by actual observation on the fluctuations of pressure and temperature occurring within steam boilers under various circumstances.

With this view the writer affixed three thermometers (made specially for the purpose by Messrs. Schaeffer and Budenberg) to different parts of the boiler of a locomotive, viz., one in the front of the boiler, close to the entry of the feed-pipe, and, therefore, where the lowest temperature might be looked for; the second about the middle of the length of the fire-tubes, where the temperature would probably be highest; and the third in the front of the fire-box and near its top. A large series of observations were taken of these thermometers by competent persons, and at short intervals. The results are embodied in a table, which gives for each observation, (1) the actual pressure at the moment as given by the pressure gauge, in atmospheres; (2) the readings of each of the three thermometers; (3) the theoretical pressure of steam corresponding to each of these temperatures, as calculated by the formula of Regnault. The observations fall into four groups according to the following condition: (A) engine standing, feed shut off; (B) engine standing, feed going on; (C) engine running, feed shut off; (D) engine running, feed going on. Separate observations were taken with three different descriptions of feed apparatus, viz., an injector, a plunger pump, and two plunger pumps combined. Separate series of observations were also taken when the pressure was rising, and again when it was falling.

The pressure as given by the gauge in every case differed from the theoretical pressure deduced from the temperatures. As these latter always varied among themselves, exact agreement was of course impossible; but this was not enough to account for the differences observed, which may possibly be attributed to defects of the gauge, but should

rather be taken into account among the general results of the experiments. These are as follows:

(1) When the feed was shut off, whether the engine was standing or running, the thermometers at the fire-box and in the middle of the boiler gave very nearly equal readings. At the smoke-box end the temperature was somewhat lower, but the difference was not above 5°.

(2) With the feed shut off, but with rising temperature and pressure, the indicated tension of steam in the steam space was about 0.2 atmosphere (3 lbs.), higher than the theoretical pressure at the hottest part of the water: with falling temperature and pressure it was about as much lower.

(3) When the feed was opened the temperatures at the three places fell unequally; the fall being least in the middle, greater at the fire-box, and greatest at the smoke-box near the entry of the feed pipe.

(4) Where the feed was effected by an injector these differences were least, not exceeding 7°; with a single pump they amounted in some cases to 9½°, and with two pumps to as much as 17½°, corresponding to a difference of pressure of 2¼ atmospheres (about 35 lbs.).

(5) A fall in the temperature of the water was in all cases followed by a fall in the tension of the steam; but when the cooling was rapid this fall was less in proportion to it, so that the actual tension became higher than the theoretical pressure at the points of observation. The greatest difference so observed amounted to 2¾ atmospheres.

(6) While this held in general, there were cases where, at the commencement of the feed, the theoretical pressure at the hottest point was for a short period higher than the actual steam tension, the greatest difference, however, not exceeding 0.43 atmosphere.

(7) When the injector was used the temperature of the feed-water, immediately before entering the boiler, was from 40° to 60° higher than that of the tender-water. This, of course, accounts for the inequalities of pressure produced by an injector being much smaller than by a pump.

(8) A sudden opening or closing of the regulator produced an instant fall or rise of the pressure gauge of about 3 lbs., or 1½ lbs. respectively, followed in general by a slight recoil towards the original standpoint.

(9) The opening of the regulator caused a rapid fall of the thermometer which at that moment stood highest, and a rise of that which stood lowest, amounting in each case to about 3½°, thus producing an equalization of temperature to the amount of about 7°.

The following general conclusions are drawn from the above facts by the writer:

(1) The supply of water by feed-pump causes large variations of temperature in the different parts of a boiler. These act on the steam tension, but with the general result that this tension is decidedly in excess of the theoretical pressure due to the water temperature: thus fortunately tending to retard, and not to accelerate, the generation of steam.

(2) At the first moment of opening the feed the converse is observed, the steam tension being about 0.4 atmosphere in defect of the theoretical pressure. The same holds to a smaller extent when the feed is shut off, provided the temperature and pressure are falling at the time.

The explanation of the above facts is obvious. When the pressure is lessened by the steady abstraction of steam it falls steadily both in the water and the steam space. When the abstraction is rapid (as with steam blowing off) the water maintains for a time a higher temperature than the steam space, with a corresponding generation of steam. When the pressure is lessened by actual cooling of the water, the steam only follows it gradually, and keeps up for a time a higher tension. The slight converse effect, at the moment of opening the feed, is accounted for by the additional consumption of steam due to the feed-pump, and perhaps by a slight condensation of steam effected by the first entry of the cold water.

(3) When the temperature and pressure are rising instead of falling, the steam tension will similarly appear in excess or in defect of the theoretical pressure, according as the original cause of the rise is a checked consumption of steam or a more rapid generation. The first case is shown in the experiments

when the engine was standing, the second on several occasions when it was in motion.

(4) Wherever pressure is taken off water, which is above the boiling point, a sudden generation of steam must ensue. This has been actually observed in the experiments to take place to the amount of ½ atmosphere under ordinary conditions. In exceptional cases it might be much greater, especially when the large differences of pressure at different parts of the boiler (sometimes amounting to thirty lbs.) are taken into account. The sudden spring of the pressure gauge at the opening and shutting of the regulator indicates the violent effects which rapid changes of this kind would produce in a mass of vapor at high tension. The Author thus considers himself to have shown that under a rare but not impossible combination of unfavorable circumstances, a sudden generation of steam might occur violent enough to burst, if not a new boiler, at any rate one deteriorated by long working. At the same time the much slighter effects of this kind produced by an injector, as compared with a feed-pump, should be noted as forming a substantial advantage on the side of the former.

INFLUENCE OF THE MOON ON THE EARTH'S MAGNETISM.

By JOHN ALLAN BROUN.

From "Nature."

THERE is a fact in connection with the moon's influence on our earth for which an explanation is necessary, and M. Faye has proposed for this end a hypothesis in advance. He had already pointed out Dr. Lloyd's investigation which showed that the diurnal magnetic variations could not be explained by the hypothesis that the sun acts as a magnet. But, it is said, "May the moon not acquire induced magnetism under the action of the earth, perpetually variable according to the relative position of the two bodies? If we consider the enormous magnetic power of the earth, that Gauss finds equal to that of 464 trillions* of magnets weighing a pound each, and if we remark besides that the distance of the moon to the earth does not exceed thirty times the length of this gigantic magnet, we may give an affirmative answer to the question proposed. But then the magnetism induced in the moon should in its turn exercise a small action upon the proper magnetism of the earth in the period of a lunar month. The observations alone can decide this provided they are of great precision."

M. Faye then cites the results obtained from the Toronto observations by Gen. Sir E. Sabine, that for the magnetic declination showing a range of 0.64; and he adds, "All these effects are of double period; they show two maxima and two minima in the course of the lunar month of 29½ days, which proves that they are due to an induced or reflex action, not to a direct action of the moon herself." I shall put my remarks on this subject under three heads.

1. Is such a result possible for the moon's synodical revolution? Let us commence with full moon at the winter solstice; near this epoch the moon is in the plane perpendicular to the ecliptic passing through the earth's magnetic axis and the sun. The north pole of the terrestrial magnet is then presented to the moon in such a way as to produce the maximum of induction; when the moon is near her third quarter the two terrestrial magnetic poles will be equidistant from the moon and the inducing action will be a minimum; there will be a second maximum near new moon when the south pole is most presented to our satellite and a second minimum near the first quarter. If now we follow the earth in her revolution to the vernal equinox, we shall find all this changed. At full moon our satellite is then equidistant from the two terrestrial poles, and the inducing action is a minimum;

* M. Faye uses the word trillions, but the trillions are English, not French, the latter being a very different number.

it is a maximum, on the contrary, near the first and third quarters. The consequence will be that if any inducing action existed it would have the same value at all ages of the moon in the mean of observations made during a series of years, such as were employed by Sabine for the variations in question. Such a result, however, as has been imagined by M. Faye might be possible if, instead of the synodical, we employ the tropical revolution of the moon, which occupies nearly 27.3 days.

2. We may inquire, then, if the moon as a permanent or induced magnet can produce any magnetic variations appreciable by our instruments? In the first place, Mr. Stony has shown that if the moon were as magnetic, bulk for bulk, as our earth, her whole action in deflecting a freely-suspended needle in our latitudes could not exceed one-tenth of a second of arc (0″.1). In order to consider the question of the variable magnetism induced in the moon by our earth, let us suppose her inductive capacity equal to that of cast-iron. From Barlow's experiments at Woolwich with iron balls I find that the magnetism induced in an iron ball of one foot diameter is about 2.0, in English units, which is nearly twice the magnetic force given by Gauss for the same volume of our earth. Barlow found the induced moments of different balls to vary as their volumes, and assuming that the induced magnetism varies inversely as the cube of the distance of the inducing and induced bodies, we find at the moon's distance (60 terrestrial radii) the induced magnetism at the maximum, under the most favorable condition, could not be more than $\frac{2}{60^3}=\frac{1}{108{,}000}$ of that supposed in the first case, that is when as magnetic as the earth. Her whole action on a magnetic needle here, then, due to the earth's induction, could not exceed one millionth of a second of arc. It is advantageous to get rid of hypotheses which are so completely insufficient, and we may put aside for the future any consideration of the moon's action by her own permanent magnetism, or by a variable magnetism induced in her by the earth.

3. M. Faye has also misunderstood the facts which he wished to explain. The results obtained by Sabine have reference to a variation which occurs in $24\frac{3}{4}$ *hours*, the lunar *day*, and not the lunar month of $29\frac{1}{2}$ days. The laws of the lunar diurnal variations were obtained first by Kreil for the magnetic declination, and by myself for the magnetic force and inclination. This action of the moon is, however, so very different from what is generally supposed, and from what was concluded from the first investigation on the subject, that it is of the greatest importance, in relation to the whole question of cosmic meteorology, I should state some of the more marked facts which have been deduced from eleven years' hourly observations on the magnetic equator. I shall limit myself at present to the lunar actions on the *direction* of the horizontal magnetic needle.

The moon, in a lunar day of 24.7 hours, produces a variation in the earth's magnetism, such that the magnetic needle makes *two* complete and nearly equal oscillations from an easterly to a westerly position in the interval in question. This is the general *mean* law. We have seen, in considering the law of the solar diurnal variations that, near the magnetic equator, the law becomes reversed when the sun passes from the one hemisphere to the other, so that when the sun is north, the movement of the needle is like that in high north latitudes, and when south, like that in high south latitudes. If, then, the moon acts in the same way as the sun, we should expect a similar phenomenon for the lunar diurnal variation when the moon crosses the equator. This is not the fact. The law differs little for the position of the moon north and south of the equator.

There *is*, however, an inversion of the lunar diurnal oscillations; thus, in the months of December and January the north end of a magnetic needle is farthest *east* when the moon is on the upper and lower meridians, and farthest west near moon-rise and moon-set; whereas in the months of June and July the reverse is the case, the north end of the needle being farthest *west* when the moon is on the meridian (upper and lower) and farthest east when she is on the horizon. It followed from this, as for the solar diurnal law, that the

oscillations should be in opposite directions at the same time in the higher latitudes of the two hemispheres, as has been found to be the case.

It is not then when the moon crosses the equator but near the times when the *sun* does so, that the moon's action is reversed.

The dependence of the lunar action on the position of the sun becomes more evident as the investigation becomes more detailed. When we determine the mean law for each month of the year, we find that the north end of the needle moves equally far east and equally far west at each of the two oscillations in the lunar day; this is not found to be the case for different positions of the moon relatively to the sun. Thus in the quarter lunations including full moon, in the months of December and January, the greatest *west-east-west* oscillation of the needle occurs when the moon is on the *lower* meridian; not when the moon, but when the *sun*, is shining on the place of the needle. The oscillation from moon-rise to moon-set, that is to say, while the moon is above the horizon, is little more than one-third of the oscillation for the half day when she is below the horizon; the two westerly extreme positions when the moon is on the horizon are nearly the same.

Similar results are obtained for the other quarter lunations. In all cases that oscillation is the greatest of the two for which the sun is above the horizon, whether the moon be above it or not.

There are still some remarkable facts connected with this variation at the magnetic equator. Limiting our examination of them always to December and January, we find, if we determine the oscillations due to the moon for the day when she is in conjunction and for each of the six following days, that in the first three days of the seven the oscillation is *west-east-west* during *the day*, that is, from sunrise to sunset; and in the last three days it is *east-west-east*. In the middle day of the seven the lunar action is almost null; the oscillation of the needle is very small, as we might expect, since on that day the change at sunrise from a *west-east* to an *east-west* motion takes place. The lunar hours of the maximum and minimum extremes thus oscillate about two hours on each side of the mean, depending on the position of the moon at *sunrise*.

The action of the moon, then, is dependent on the sun's position relatively to the equator (or the earth's position in its orbit), and on the position of the moon relatively to sunrise and sunset. But there is no relation between the laws and amplitudes of the solar and lunar diurnal oscillations. In the months from which I have taken my illustrations, the solar diurnal variation is a single oscillation; that for the moon, however taken, for single days, for quarter or for whole lunations, is always double. Through the combination of all the varying modes in which this oscillation is produced from day to day, *the mean for a lunation* is a regular double oscillation. The amplitude of this mean oscillation is three times as great in January as in June or July; whereas the amplitude of the mean solar diurnal variation is a half greater in June or July than in January.

I shall add another fact, one of the greatest importance in connection with this subject. We have seen that the lunar diurnal variation changes in the relative *amplitudes* of the two oscillations from day to day; the consequence of this is that when the means for a whole lunation, or even a quarter lunation, are taken, the mean amplitude is much less than that which is shown by each day separately. Thus I have found that the range of the mean lunar diurnal oscillation for the lunation December 16, 1858, to January 15, 1859, at Trevandrum, was 1′.25, while the ranges of the mean oscillations for the quarter lunations varied from 1′.70 2′.70, these quarter lunations giving exactly the same laws as have been deduced from eleven years observations for the same lunar epochs.

In order to understand the value of these results we must compare them with the ranges of the solar diurnal oscillations for the same months; those for December, 1858, and January, 1859, were 2′.20 and 2′.24 respectively. And as on some days the lunar diurnal variation has amounted to nearly 5′.0 (which is equivalent to 12′ in England with the smaller directive force), it appears that the lunar action is sometimes greater than the solar action at the magnetic equator.

As long as the lunar diurnal action was considered to be of the minute character first discovered, it was always possible for the supporters of the heat thesis to suspect that some small unknown heat action was in question. Such an idea is no longer possible. The lunar is sometimes greater than the solar diurnal action; and the former is dependent for its magnitude on the light and heat vibrations *due to the sun* shining on the place of the magnetic needle.*

If the solar light and heat vibrations can increase the magnetic action, there can be no difficulty in believing that these vibrations may in their turn suffer some modification of intensity. It would be difficult to measure small variations of the sun's light with sufficient accuracy as yet, though Mr. Willoughby Smith has suggested a selenium photometer for this end; we can, however, measure the variations of temperature, and the fact that the direct heating action of the moon is inappreciable is no longer sufficient to disprove the results of Madler, Kreil, Park Harrison, and Balfour Stewart. We have in fact a mode of lunar action with which M. Faye was unacquainted and could not take into account. The whole basis of his argument is therefore destroyed.

The view now given opens up a wide field of inquiry, and cosmic meteorology appears under another aspect. I hope to be able at another time to present other facts which seem to relate to magnetical and meteorological phenomena.

* Mr. Willoughby Smith's experiments show that the light vibrations of the ether in selenium diminish in a very marked manner the electrical resistance of the crystal; and it does not seem improbable that the increase of the lunar magnetic oscillation in sunlight may be due to some similar action.

THE SEWAGE SYSTEM OF PARIS.

From "Engineering."

In anticipation of the intended visit to the sewage system of Paris, by the Institution of Mechanical Engineers, during the forthcoming visit of that body to Paris, we propose to bring together a few notes upon the subject, which may be found of interest.

The area enclosed within the fortifications of the city may be put down at 19,000 acres. The quantity of water distributed for miscellaneous service over this area per day is about 46,000,000 gallons, and the average daily rainfall is some 22,000,000 gallons. About twenty per cent. of this quantity is absorbed by evaporation, leaving 54,400,000 gallons to be dealt with. This water is loaded with the *debris* from the streets, and the impurities from manufactures, house refuse, stables, &c. The sewage properly so called does not enter the sewers, as it is dealt with separately. Roughly speaking there are about 100,000 water-closets in Paris, of which a small proportion is provided with separators that retain the solid excreta, while permitting the liquid portions to pass into the sewers; the remainder are chiefly emptied into cesspools. The present system is of very recent date, but partial drainage works for conveying the sewage into the Seine were constructed at a very early period. In 1831 the remains of sewers dating from the time of Philippe le Bel were found underneath the Palais de Justice; but the conduits then formed were only for the service of a few palaces or other important buildings. In early times the Cite discharged its sewage into the Seine, the University quarter on the left bank, into the Bievre, and the town, properly so called, into the Menilmontant brook. As for the neighboring slopes of Charonne, Menilmontant, Belleville, and Montmartre, the porous surface soil absorbed a large proportion of the sewage, which—partially filtered—found its way into the Seine. The brook of Menilmontant was through several centuries known as the main sewer of Paris, and many roughly constructed channels were made from time to time to converge into it. About 1550 under the reign of Henri II., a very important effort was made to improve the condition of the city. A scheme was prepared by an en-

gineer of the period—Gilles Desfroissis—to divert the water of the Seine into the sewers and channels, natural and artificial, and by means of sluices to create a constant current of water, which should carry away all obnoxious matter down to a suitable point of discharge. This project, however, was opposed by the city, and nothing came of it. In 1605, under Henri IV., Prevot Francois Miron arched over at his own cost the Ponceau sewer, which extended from the Rue St. Denis to the Porte St. Martin. In 1611, Hugues Cosnier, director-in-chief of the Loire Canal, revised the project of Desfroissis but failed; in 1631, engineer Pierre Pidou was charged with the work of enlarging the city by enclosing within the *enceinte* of the Tuileries, the Faubourg St. Honore as far as the Rue Royale, and the Faubourg Montmartre as far as the present boulevards. In the course of this work he made the sewers navigable from the Arsenal to the Porte de la Conference, and constructed near the walls of the city a large sewer twelve feet in width. At this time there were about 12,000 yards of sewers of all kinds in and around Paris, the greater portion in so bad a condition that many workmen employed in repairing them were killed. It may be worth noticing that the physicians of the period on inquiring into the cause of these deaths, so far from recognizing the real reason, reported that the men in question were killed by the stare of a basilisk which they asserted inhabited the sewers. In 1667 the service of police was created, and shortly after a municipal ordonnance enjoined an annual inspection of the sewers by the various prevots, who were to take steps for their maintenance. But in spite of this, matters went from bad to worse, the sewers became choked and absolutely useless, even to convey the sewage into the Seine, where it had so long been a grievance to the water-side population; and on the 24th of April, 1691, a decree was issued for the formation of a commission to study the whole subject and devise a remedy. In a map of Paris, dated 1592, the brook of Menilmontant as it then existed is shown. The banks were sloped and planted with trees, and its principal tributaries were the sewer from the Rue des Egouts, between Rue St. Martin and Rue St. Denis, the Montmartre sewer, and the Gaillon sewer, which afterwards was converted into the Rue de la Chaussee-d'Antin. The land in its vicinity was deserted, for no houses could be occupied near it. But it was not till about 1730 that extensive operations were undertaken to ameliorate the condition of the city. Michel-Etienne Turgot, father of the great minister, engaged seriously in the work; he constructed an open channel in stonework, and provided means for its easy cleansing, and he formed also a reservoir at the end of this canal to receive the contents of the Belleville sewers, which then flowed through the canal. A map, dated 1765, shows the extent of the works carried out by Turgot. The canal followed the Rue des Fosses-du-Temple, where for part of its length it was arched over, but was left open between the Porte du Temple and the Porte St. Martin to receive the Sewer du Temple and the Sewer de la Croix; it then passed through the faubourgs of St. Martin, St. Denis, Montmartre, and Poissoniere, and was there partially covered over and planted with trees. It was left open again to receive the sewer of the Rue St. Lazare, and passing beneath Rue de la Chaussee-d'Antin, it penetrated through the Faubourg St. Honore, and the middle of the Champs Elysees, to fall into the Seine. Gradually the work of extending and improving the sewers was carried on, and in 1806 there existed about 79,700 feet covered, with the exception of 5200 feet. During the reign of Louis Philippe about 80,000 yards of additional sewers were made; but their usefulness was only partial, and the sanitary condition of the streets was bad in the extreme.

In 1855 the works which were to transform the whole system of sewage collection were commenced, the projects having been previously elaborated by the late M. Belgrand, Ingenieur des Ponts et Chaussees. At that time there were about 145,000 yards of sewers for 425,000 yards of streets, while at present there exist some 775,000 yards of sewers for 860,000 yards of streets. About 148,000 yards is the length of the service drains of the dwelling-houses. The system as now carried out is divided into two classes, the sewers and the collectors; the former receive the street and house

water, and conduct it to the collectors. The latter are constructed along the lower levels of the city to receive the natural drainage, as well as the contents of the sewers. They are three in number. The first is on the right bank of the Seine, and is known as the Departmental collector; it commences at the point of intersection between the Rue Oberkampf and the Rue Menilmontant, and passes under the old boulevards. Its course is broken by three bends, by which it crosses the basin of La Villette, the fortifications, and the Grande Route St. Denis, until it falls into the Seine, near the Ile St. Ouen. The sewage dealt with by this collector is of the worst kind, containing, as it does, the impurities from the abattoirs, gas works, the factories of La Villette, Montmartre, &c., and even the overflow from the Bondy depot. The second collector on the right bank of the river commences at the Arsenal basin, following the quays, and running under the Rue Royale, the Boulevard and Rue Malesherbes, it traverses the Route d'Asnieres and falls into the Seine above the railway bridge. At the Place du Chatelet it is increased to receive the contents of the collector of the Boulevard Sebastopol; at the Place de la Concorde the sewer of the Rue de Rivoli joins it; at the Place de la Madelaine it absorbs the sewer of the Petits-Champs, and at the junction of the Boulevard Malesherbes and the Rue de la Pepiniere, a sewer following the course of the brook of Menilmontant flows into it. On the left bank there is only one collector, which at its commencement absorbs the river Bievre, that at one time used to flow into the Seine above the Pont d'Austerlitz. The collector taking this stream runs behind the Jardin des Plantes, towards the Boulevard St. Michel, when it passes along the quays as far as the Pont d'Alma; here a double siphon takes it across the river, when the gallery passing under the height of Chaillot and the Avenue Wagram, crosses the village of Levallois-Perret, and joins the collector on the right bank last described, about 550 yards from the point of discharge. Near the Pont d'Alma on the left bank, it receives the Montparnasse sewer, and the Grenelle collector; on the right bank the Auteuil collector falls into it.

As an indication of the form and arrangement of the galleries, we may give a few particulars of the great collector on the right bank, the course of which has been already indicated. The section is a gradually increasing one to accommodate the discharge from the various tributaries flowing into it. The sewage water flows in a channel, on each side of which is a paved side walk, the whole being inclosed within a semicircular arch. The collector is composed of four different types, Nos. 6, 5, 3, and 1. The total length is 27,207 feet, and the lengths of the different sections are respectively 2296 feet, 2853 feet, 7019 feet, and 15,039 feet. Type No. 6 extends from the canal St. Martin to the Rue St. Paul; type No. 5 from that point to the Boulevard Sebastopol; type No. 3 from the Boulevard Sebastopol to the Place de la Concorde; and type No. 1 from this point to the discharge at Asnieres. Type No. 6 is 8 feet $2\frac{3}{8}$ inches wide at the point of springing of the arch, the height from the side galleries to the point of springing is 4 feet $11\frac{1}{8}$ inches, and the side walls are curved with a radius of 18 feet $9\frac{1}{8}$ inches; the width of the side galleries is $35\frac{1}{2}$ inches on one side, and $15\frac{3}{4}$ inches on the other, and the width of the channel is $31\frac{1}{2}$ inches. The depth of the channel in the middle is $15\frac{3}{4}$ inches, the invert being curved. The thickness of masonry is $10\frac{5}{8}$ inches inside the invert, the bottom of the structure being flat, 7 feet $6\frac{1}{2}$ inches wide. The thickness of the side walls and arch is 13 inches, and the interior of the sewer is covered throughout with a lining of cement $1\frac{3}{16}$ inches thick. The outside of the arch is also protected with cement. Type No. 5 is 9 feet $10\frac{1}{16}$ inches wide at the springing of the arch, the height of the side walls to springing is 4 feet $11\frac{1}{8}$ inches, and the radius to which they are curved is 12 feet $9\frac{1}{2}$ inches. The widths of the side walks are $27\frac{9}{16}$ inches and $19\frac{1}{16}$ inches respectively, and that of the channel is $47\frac{1}{4}$ inches. The depth of the latter is $31\frac{1}{2}$ inches in the center and $27\frac{9}{16}$ inches at the sides; the thickness of walls and arch is 13 inches, and the thickness underneath channel is $11\frac{13}{16}$ inches. The underside of the structure is flat and about 6 feet wide; this, like all the other sections, is lined throughout with

cement. Type No. 3 is 13 feet $1\frac{7}{16}$ inches wide at springing; the height from side walks to springing is $35\frac{7}{16}$ inches, and the side walls are curved with the same radius as the arch, so that the section of this type is more than a semicircle. The side walks are both $27\frac{9}{16}$ inches wide, and the channel is 7 feet $2\frac{1}{4}$ inches wide. The depth of the latter is $39\frac{3}{8}$ inches in the middle and $31\frac{1}{2}$ inches at the sides, the thickness of masonry under the channel is $17\frac{11}{16}$ inches and at the sides it is $23\frac{5}{8}$ inches. The under side of this section is curved on the exterior. Type No. 1 is 18 feet 3 inches wide at springing and 23 feet 7 inches wide on the outside of the masonry, the arch is elliptical and the height from springing to center is 6 feet 4 inches; the side walls are curved and are 3 feet 5 inches high from the side walks to the point of springing. The walks themselves are 2 feet $11\frac{1}{2}$ inches wide, and the width of the channel is 11 feet 5 inches. The depth of the latter is 6 feet 11 inches.

The normal distances between the underside of the masonry and the street levels are as follows for the different types except No. 1.

	ft.	in.
Type No. 3	16	$6\frac{3}{4}$
" No. 5	15	$10\frac{1}{16}$
" No. 6	13	$6\frac{9}{16}$

The gallery under the Boulevard Sebastopol may be taken as a type of one of the branch collectors. It was constructed between 1855 and 1858 under one of the side avenues of the boulevard from the Boulevard St. Denis to the Quai de la Mégisserie; from this point it extends with type section No. 6 under the Boulevard de Strasbourg, as far as the Rue du Chateau-d'Eau. In ordinary work this gallery serves as a collector for the flat district known as the Marais; during heavy rains it discharges the overflow direct into the Seine, and renders impossible the floods which used to be common in the Faubourgs St. Martin, St. Denis, Montmartre, &c. In this gallery are laid the two great water mains which receive their supply from the Ourcq. The following are the principal dimensions of the gallery:

	ft.	in.
Length	5074	0
Width at springing of arch	16	$0\frac{1}{2}$
Height from side walks to top of arch	11	$11\frac{3}{8}$
Width of side walks	2	$7\frac{1}{2}$
Width of channel	3	$11\frac{1}{4}$
Depth "	4	$3\frac{9}{16}$
Height of side walls	3	$11\frac{1}{4}$
Thickness of arch at crown	1	$7\frac{11}{16}$
" " springing	2	$11\frac{9}{16}$
Thickness of cement lining	0	$1\frac{9}{16}$
Distance apart of ventilators	164	0
" of street connections	328	0
Height of branch to street traps	6	6
Width " "	2	$7\frac{1}{2}$

The edges of the side walks of this gallery, as well as of all except the largest sections, are furnished with rails, along which the wagons run, which are employed for cleaning out the channels. These wagons consist of a light frame running on wheels and furnished with a movable dam turning on an axis in the wagon, and being manipulated by a winch. Its form corresponds to that of the channel. When it is desired to remove any obstruction in the channel the dam is lowered, backing up the water behind, which being suddenly released carries with it the accumulation of sand, mud, &c. For the larger sections, boats are employed instead of the wagons. These are built of iron, and carry a movable dam in front similar to that attached to the wagons. Projecting from the boat are two arms carrying guiding wheels, which pressing against the sides of the channel keep the boat in the center. When the dam is lowered the water behind it forms a head of from 6 inches to 12 inches, which is sufficient to produce the desired effect. The deposits accumulating below would quickly form a bank that would stop the progress of the boat, if the water in escaping through the spaces between the sides of the dam and the channel, and by small openings made in the former, did not drive the sand and mud constantly in advance of the boat. The rate of progress is very slow, as it takes from eight to ten days to traverse the five miles of the grand collector. In returning up stream movable dams are placed in the channel about every 600 yards, to reduce the speed of the current. Safety chambers for the workmen are placed at intervals of 650 feet. This precaution is very necessary, since in periods of heavy rains the collectors are

quickly flooded, as, for instance, on the 27th of July, 1872, when in five minutes the Sebastopol collector was filled to the roof, and several workmen were drowned. There are about 7000 points of egress for the workmen in case of necessity. The number of men employed in cleansing the sewers is about 700.

By means of the collectors nearly all the sewage water is discharged into the Seine far beyond the limits of the city. But this is done at the expense of the river lower down, chiefly on account of the great deposits of material held in suspension, since, as we have seen, the house sewage proper is not admitted into the collectors, but is removed from the cesspools by carts. Dredging operations are constantly necessary, and about 120,000 tons of *débris* are removed annually from the Seine, at a cost of some £6000. To obviate this evil, sewage utilization works have been established for some years on a comparatively small scale at Gennevilliers, and larger ones are now in contemplation.

A commission was lately appointed by the Prefecture of the Seine to examine into a project for the construction of irrigation canals which should take the sewage water from the collectors and distribute it upon suitable land in the vicinity of Paris, with the object of improving the soil and also to convert the impure waters into an effluent that might filter gradually into the Seine. It will be observed that this project is an extension of the sewage utilization scheme already carried on at Gennevilliers. The new project includes the construction of a main irrigation canal extending from Clichy to the Forest of St. Germains, of six secondary branches, and of a large number of channels which collectively should irrigate an area of 16,000 acres.

The total length of the principal channel would be about 18,000 yards. It would be circular in section, 6 feet 6 inches in diameter, and would traverse the Seine three times by siphons in cast iron. The pumping station would comprise five engines, collectively of 1200 horse power, of which two are already at work in pumping the sewage for the Gennevilliers' irrigation. The estimated cost for these works is £160,000 for the pumping station and irrigation canal, &c., £40,000 for the secondary branches, or £200,000 for all, not including the outlay made at Gennevilliers, which has reached about £65,000.

The sewage utilization works at Gennevilliers were commenced in 1869 upon 14½ acres of ground, and have gradually developed until at the present time about 600 acres are under treatment. This land receives about 600,000 cubic feet of water per acre per year. The use of this water is quite optional, no cultivator is obliged to take it, and each may use what quantity he wishes, and apply it in whatever way he judges best. There are no data indicating the quantity taken by each farmer, so that only the average results are known.

The irrigated soil is generally laid in ridges separated by trenches; the trenches receive the water, and the ridges are reserved for the plants. The vegetable crops are here in advance of all others, but a number of fields are occupied by potatoes, beetroot, cereals, lucerne, &c. When it is desired to have the soil less broken, it is only intersected by small trenches, generally parallel, and placed about 9 feet apart. The general appearance of the crops is most satisfactory. The vegetables, the quality of which has been much criticised, are excellent. The Horticultural Society of Paris, which has followed with the greatest interest the development of the sewage farm at Gennevilliers, has spoken of the success obtained in numerous reports. At the bottom of the open channels by which the sewage is distributed, there is a blackish deposit, formed by substances held in suspension, mineral and organic. At the moment of its formation, this deposit seems impermeable; but after having been exposed some time to the air, it has the appearance of a felt composed of hairs and vegetables and other *débris*. This deposit is left at the bottom of the trenches during one crop, and is afterwards worked into the ground. Stony ground, of which there is a considerable quantity in Gennevilliers, is much improved by the deposits of insoluble matters, mineral and organic, which the sewage waters leave on its surface, and the amount of fertile soil is thus gradually increasing from year to year.

The scheme for the extension of the

sewage utilization as elaborated by the late M. Belgrand, is as follows:

At present two 400 horse power engines raise part of the sewage water from the collector at Asnieres. Two other engines, established near the first pair, would be sufficient to pump the rest of the sewage. The invert of the St. Denis is at a much higher level, and could be discharged in the plain of Gennevilliers by gravity. From the pumping-station at Clichy to the forest of St. Germain, for a length of 16 kilometers, the water would be pumped through a main; this conduit would pass by the plain of Colombes, across the Seine, in a siphon, at the Island of Marante, would go through Bezons, Houilles, Sartrouville, then a second time over the Seine, and would enter the northern portion of the forest of St. Germain, where there are 3750 acres of sterile ground, which irrigation would fertilize; afterwards the water may be sent in a channel to Achères, where the irrigation would be extended over 1600 acres. The irrigable surfaces are approximately as follows:

	acres.
District of Gennevilliers	2500 to 3000
District of Nanterre, Colombes, Reuil	2500 to 3500
Districts of Carrières, Bezons, Argenteuil, Sartrouville	3500
Forest of St. Germain	3700
District of Achères	1750

The largest of these territories, that of the forest. would be at the disposal of the municipal service, and would constitute an immense regulator, over which the waters would run, and by which irrigation of the other districts might be controlled. For this reason this large area constitutes one of the chief advantages of the scheme.

JAPANESE METHODS OF PROTECTING THE BANKS OF RIVERS.

By W. S. CHAPLIN.

Written for Van Nostrand's Magazine.

The Japanese have worked out original methods of protecting the banks of rivers. Perhaps the peculiarity of the circumstances in which they are placed has had much to do with this fact. The rivers of Japan are all, in the upper half of their courses, rapid mountain streams, but nearer their mouths they become sluggish and generally navigable. The valuable land of the country is that which lies low enough to be irrigated. Hence the struggle, which is everywhere apparent, to keep the streams in narrow beds and retain the soil on their banks for cultivation. In the lowland portions simple earthen dykes serve to hold the water; but, at the points where the rivers change from the rapid to the sluggish character earth would not resist their action. At these points we find the structures which are described below.

The simplest form used is a basket about one and a-half or two feet in diameter, and from six to thirty feet long. This basket is filled with the rounded pebbles, which are brought down by the river, and are from six to ten inches in diameter. The meshes of the basket are made small enough to keep these pebbles in. It will be seen that such a basket when filled possesses many characteristics which are valuable in engineering; they are made of bamboo, which is always at hand in this country, and are filled with such stones as every river furnishes; they adapt themselves to the bottom whatever its shape or the changes which take place in it, and they can be made by an ordinary laborer. Bamboo is said to decay rapidly when exposed to heat, but labor is so cheap, that, perhaps, it is as economical in the end as it would be to use a more durable and a more costly wood. In many places these baskets (the Japanese call them snake-baskets or stone-baskets) are used to protect the outside of earthen banks and are simply laid against them, one resting on another.

quickly flooded, as, for instance, on the 27th of July, 1872, when in five minutes the Sebastopol collector was filled to the roof, and several workmen were drowned. There are about 7000 points of egress for the workmen in case of necessity. The number of men employed in cleansing the sewers is about 700.

By means of the collectors nearly all the sewage water is discharged into the Seine far beyond the limits of the city. But this is done at the expense of the river lower down, chiefly on account of the great deposits of material held in suspension, since, as we have seen, the house sewage proper is not admitted into the collectors, but is removed from the cesspools by carts. Dredging operations are constantly necessary, and about 120,000 tons of *débris* are removed annually from the Seine, at a cost of some £6000. To obviate this evil, sewage utilization works have been established for some years on a comparatively small scale at Gennevilliers, and larger ones are now in contemplation.

A commission was lately appointed by the Prefecture of the Seine to examine into a project for the construction of irrigation canals which should take the sewage water from the collectors and distribute it upon suitable land in the vicinity of Paris, with the object of improving the soil and also to convert the impure waters into an effluent that might filter gradually into the Seine. It will be observed that this project is an extension of the sewage utilization scheme already carried on at Gennevilliers. The new project includes the construction of a main irrigation canal extending from Clichy to the Forest of St. Germains, of six secondary branches, and of a large number of channels which collectively should irrigate an area of 16,000 acres.

The total length of the principal channel would be about 18,000 yards. It would be circular in section, 6 feet 6 inches in diameter, and would traverse the Seine three times by siphons in cast iron. The pumping station would comprise five engines, collectively of 1200 horse power, of which two are already at work in pumping the sewage for the Gennevilliers' irrigation. The estimated cost for these works is £160,000 for the pumping station and irrigation canal, &c., £40,000 for the secondary branches, or £200,000 for all, not including the outlay made at Gennevilliers, which has reached about £65,000.

The sewage utilization works at Gennevilliers were commenced in 1869 upon 14½ acres of ground, and have gradually developed until at the present time about 600 acres are under treatment. This land receives about 600,000 cubic feet of water per acre per year. The use of this water is quite optional, no cultivator is obliged to take it, and each may use what quantity he wishes, and apply it in whatever way he judges best. There are no data indicating the quantity taken by each farmer, so that only the average results are known.

The irrigated soil is generally laid in ridges separated by trenches; the trenches receive the water, and the ridges are reserved for the plants. The vegetable crops are here in advance of all others, but a number of fields are occupied by potatoes, beetroot, cereals, lucerne, &c. When it is desired to have the soil less broken, it is only intersected by small trenches, generally parallel, and placed about 9 feet apart. The general appearance of the crops is most satisfactory. The vegetables, the quality of which has been much criticised, are excellent. The Horticultural Society of Paris, which has followed with the greatest interest the development of the sewage farm at Gennevilliers, has spoken of the success obtained in numerous reports. At the bottom of the open channels by which the sewage is distributed, there is a blackish deposit, formed by substances held in suspension, mineral and organic. At the moment of its formation, this deposit seems impermeable; but after having been exposed some time to the air, it has the appearance of a felt composed of hairs and vegetables and other *débris*. This deposit is left at the bottom of the trenches during one crop, and is afterwards worked into the ground. Stony ground, of which there is a considerable quantity in Gennevilliers, is much improved by the deposits of insoluble matters, mineral and organic, which the sewage waters leave on its surface, and the amount of fertile soil is thus gradually increasing from year to year.

The scheme for the extension of the

sewage utilization as elaborated by the late M. Belgrand, is as follows:

At present two 400 horse power engines raise part of the sewage water from the collector at Asnieres. Two other engines, established near the first pair, would be sufficient to pump the rest of the sewage. The invert of the St. Denis is at a much higher level, and could be discharged in the plain of Gennevilliers by gravity. From the pumping-station at Clichy to the forest of St. Germain, for a length of 16 kilometers, the water would be pumped through a main; this conduit would pass by the plain of Colombes, across the Seine, in a siphon, at the Island of Marante, would go through Bezons, Houilles, Sartrouville, then a second time over the Seine, and would enter the northern portion of the forest of St. Germain, where there are 3750 acres of sterile ground, which irrigation would fertilize; afterwards the water may be sent in a channel to Achères, where the irrigation would be extended over 1600 acres. The irrigable surfaces are approximately as follows:

	acres.
District of Gennevilliers	2500 to 3000
District of Nanterre, Colombes, Reuil	2500 to 3500
Districts of Carrières, Bezons, Argenteuil, Sartrouville	3500
Forest of St. Germain	3700
District of Achères	1750

The largest of these territories, that of the forest. would be at the disposal of the municipal service, and would constitute an immense regulator, over which the waters would run, and by which irrigation of the other districts might be controlled. For this reason this large area constitutes one of the chief advantages of the scheme.

JAPANESE METHODS OF PROTECTING THE BANKS OF RIVERS.

By W. S. CHAPLIN.

Written for Van Nostrand's Magazine.

The Japanese have worked out original methods of protecting the banks of rivers. Perhaps the peculiarity of the circumstances in which they are placed has had much to do with this fact. The rivers of Japan are all, in the upper half of their courses, rapid mountain streams, but nearer their mouths they become sluggish and generally navigable. The valuable land of the country is that which lies low enough to be irrigated. Hence the struggle, which is everywhere apparent, to keep the streams in narrow beds and retain the soil on their banks for cultivation. In the lowland portions simple earthen dykes serve to hold the water; but, at the points where the rivers change from the rapid to the sluggish character earth would not resist their action. At these points we find the structures which are described below.

The simplest form used is a basket about one and a-half or two feet in diameter, and from six to thirty feet long. This basket is filled with the rounded pebbles, which are brought down by the river, and are from six to ten inches in diameter. The meshes of the basket are made small enough to keep these pebbles in. It will be seen that such a basket when filled possesses many characteristics which are valuable in engineering; they are made of bamboo, which is always at hand in this country, and are filled with such stones as every river furnishes; they adapt themselves to the bottom whatever its shape or the changes which take place in it, and they can be made by an ordinary laborer. Bamboo is said to decay rapidly when exposed to heat, but labor is so cheap, that, perhaps, it is as economical in the end as it would be to use a more durable and a more costly wood. In many places these baskets (the Japanese call them snake-baskets or stone-baskets) are used to protect the outside of earthen banks and are simply laid against them, one resting on another.

FIG. 1.

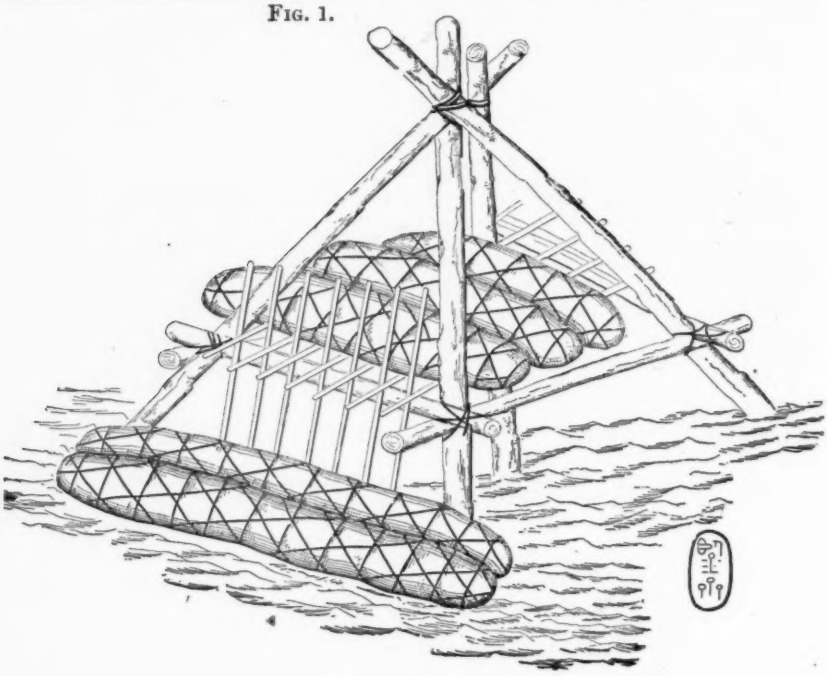


FIG. 2.

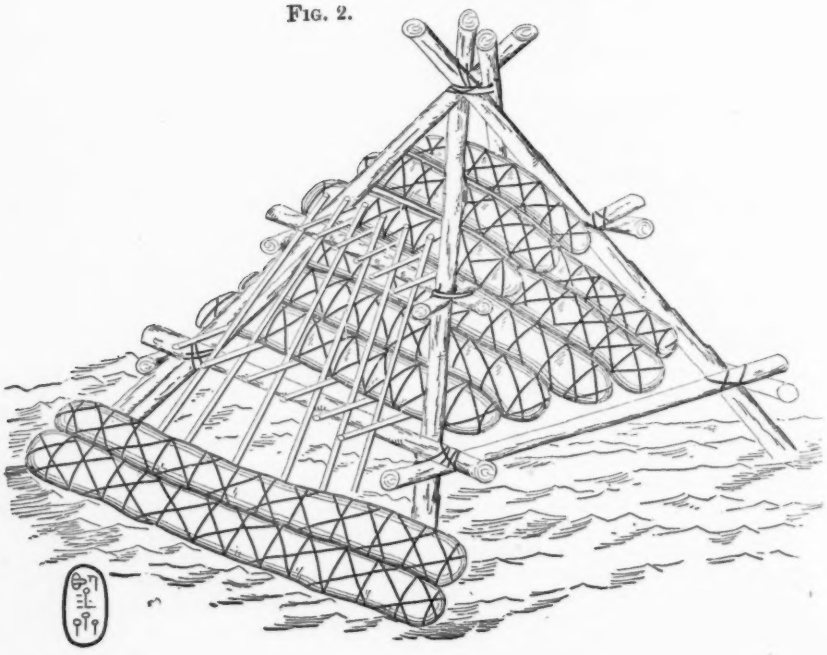


FIG. 3.

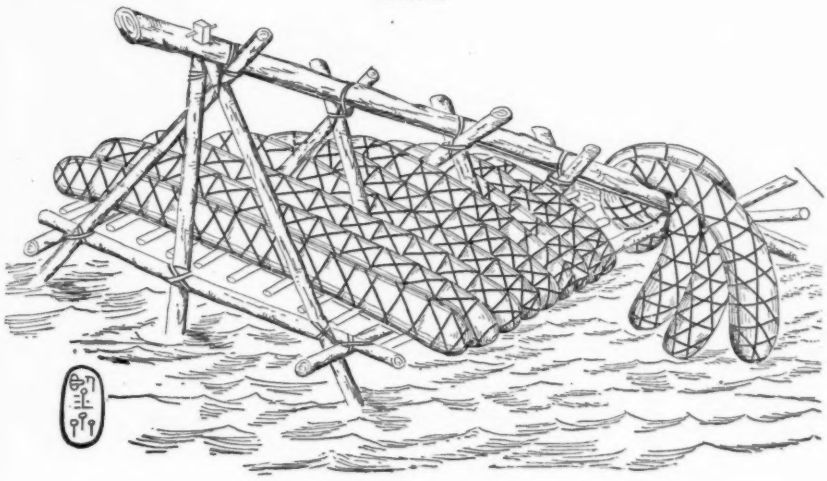
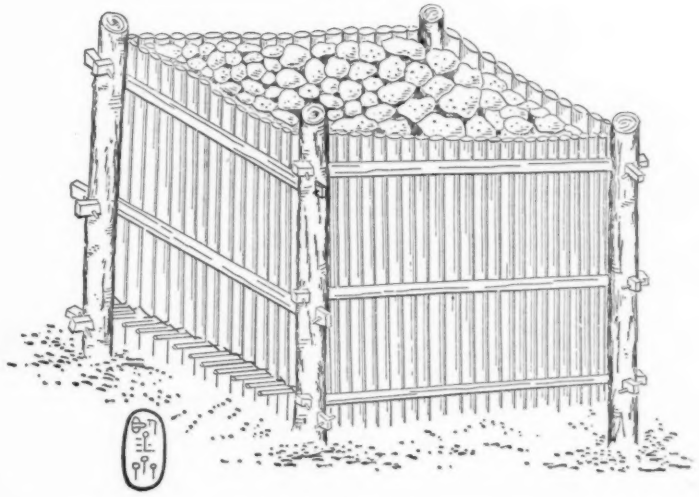


FIG. 4.



In such cases they are built or repaired during the dry season in the summer. Where a stronger current is to be resisted, the whole bank is made of baskets placed longitudinally, with a top layer laid transversely. When the exposed side needs repairs, another layer of baskets is built against it, thus increasing the strength of the bank at the same time.

To avert part of the current, but not all of it, the Japanese use such structures as are shown in Figs. 1, 2 and 3*. These trestles are made of logs about eight inches in diameter, lashed together with rough hemp ropes. Three or four feet from the bottom of the river there is a platform, on which is placed the load to keep the trestle in place. When the water is low these trestles have but little effect on its flow; but when it is high,

* The figures are from original drawings by a native Engineer.

FIG. 5.

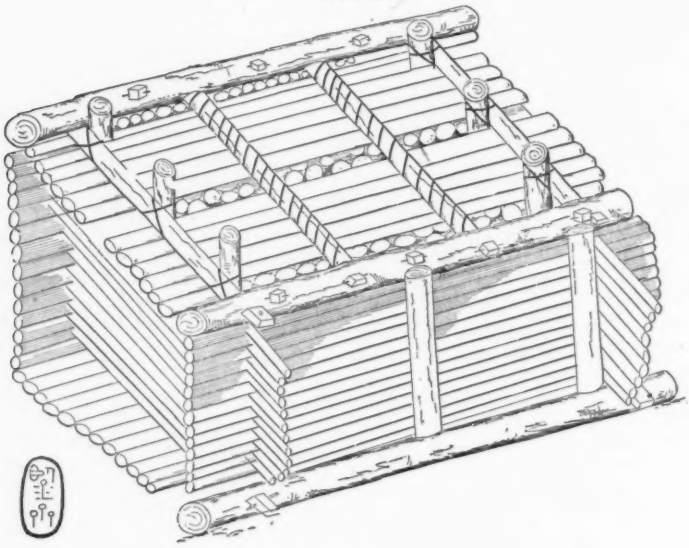
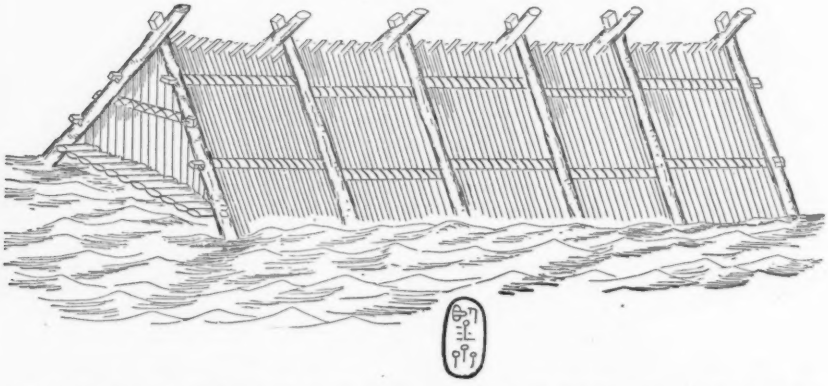


FIG. 6.



they turn away the force of it so that the bank is somewhat sheltered, while the velocity is not so reduced that a deposit is formed along the shore. To give still more protection long baskets are placed in front of the trestles as the figures show. Where the velocity of the water is very great the forms seen in Figs. 2 and 3 are used.

During low water a line of these trestles is sometimes transformed into a dam, in order to throw the water into irrigation canals. To do this long logs are placed at the water surface from one trestle to the next. Then bamboos are driven into the bottom along the logs about three feet apart, so that the river bottom supports the lower ends and the logs the upper. Mats are placed against the bamboos, and earth or sand is thrown against the bottom of the mats. Such a dam is very tight and effective until high water comes; when the mats and bamboos are carried down stream, the logs, being fastened only at one end, swing around into the line of the current and

all possible space is left for the flow of the water. Bamboo is very generally used in all constructions for bank improvement; but other woods are used where greater strength or framing is necessary. Iron is never used, but all connections are either made by lashing or by mortices and tenons and pins. Figs. 4 and 5 show two common forms of crib work; that shown in Fig. 4 is adapted to soft bottom, and that in Fig. 5 to rocky bottom. In both forms there are platforms at about half their height above the bottom, on which the loading stones are placed.

Fig. 6 shows a peculiar form of crib work. The frame is made of logs, and the sides are filled in with bamboos which are lashed to the cross pieces.

THE TRANSMISSION OF MOTION TO A DISTANCE BY MEANS OF ELECTRICITY.

By M. CADIAT, Engineer.

Translated from "La Nature" for VAN NOSTRAND'S MAGAZINE.

THE employment of electricity for the transmission of motion to a distance is an accomplished fact. For some months, I have controlled the machinery of a workshop, situated some distance from the motor, with only such connection as was afforded by a conductor of an electric current.

The Société du Val d'Osne owns an electroplating establishment at Paris, in which copper-plating is constantly in progress. The electricity was furnished by a Gramme machine, which was run by a portable engine at considerable expense and trouble.

The idea of using two Gramme machines suggested itself to me. The machines have, heretofore, served for lighting the shops in winter. Machine No. 1 was attached to the horizontal shaft at the millwright's shop. This was the *generator* of the electricity. The second was placed in the electro-plating shop, 150 meters distant. This was the *receiver* of electricity. The two machines were connected by a double wire. The current received at the second machine was transformed into work, by which the electro-plating machine was kept in motion.

It is a month since the plan was put in operation, and there has been no irregularity in its working. No superintendence is necessary. The arrangement is as simple as can be desired, and the motion is started or stopped by simply connecting or disconnecting the conducting wire.

One advantage of the system lies in the ability to vary the velocity of the receiving machine. It is accomplished by varying the resistance of the conducting wire. Thus the velocity of the machine No. 2, being 750 revolutions, if a copper wire two meters long, and one-and-a-half millimeters in diameter, be introduced into the circuit, the velocity is reduced by forty revolutions. If an iron wire of one-and-a-half meters in length and $\frac{8}{10}$ of a millimeter in diameter be used, the velocity is reduced by 100 revolutions.

When the portable engine was employed to run the electro-plating machine, the expense was about twenty-four francs per day. Now the cost is inappreciable. For if there is any extra consumption of fuel in the driving engine at the millwright's shop, it is not noticeable, and the engineer cannot detect the stopping or the starting of the Gramme machines by any irregularity of his motor, which is only a ten horse-power engine.

When the No. 1 machine is employed for lighting purposes, it absorbs a sensible amount of the power of the engine. It is estimated to require in general two horse power for its successful working.

This is certainly not the last that is to be said upon this question. We have employed two machines used for lighting and not designed for the purpose for which they are employed. We do not flatter ourselves that we have obtained a maximum result.

Should the two machines have the

same or even similar dimensions? Ought the first to possess higher tension or greater quantity than the second?

These questions are yet to be answered. At present we are content to announce that the transmission of motion to considerable distance by an electric current is a practical possibility.

WOHLER'S EXPERIMENTS ON THE STRENGTH OF GIRDERS AFTER REPEATED CONCUSSIONS AND STRINS ON IRON BRIDGES.

By Dr. E. WINKLER, Professor of the Polytechnic School at Vienna.

From Foreign Abstracts of Institution of Civil Engineers.

The Author discusses the results of Wohler's experiments on the effect of repeated strains and blows on iron, and attempts to apply these results to iron girders, most of Wohler's trials having been made on axles and tires. The Author points out the empirical nature of the present calculations for wrought-iron bridges, showing that the most elaborate analytical work is in practice nullified by the fact that the immediate effect of the blows received by a girder from the moving load, as also the ultimate effect of these blows lasting for years, have not yet been expressed in a mathematical form, and have not been introduced in the usual formulæ. The consequence is that engineers have been obliged to assume so large a margin of safety that accurate calculations of the cross sections of iron are to some extent useless; for, the effect of the forces above mentioned not being ascertained, the bridge may be a great deal too strong, or even not strong enough. After alluding to the great increase in the weight of locomotive engines in the last ten years, which has diminished the margin of safety in the old girder bridges, Dr. Winkler considers the effect of the permanent load in comparison with that of the passing trains, and comes to the conclusion, that the heavier the girder, the less will be the immediate as well as the ultimate effect of the moving load on the iron: in other words, the margin of safety should be greater for bridges of small span than for large ones. Messrs. Klett and Co., of Nurnberg, have constructed many bridges in Germany, on the principle that the admissible strain per square inch on wrought iron should be $3\frac{3}{4}$ tons per square inch for bridges of 30 feet span, increasing to $4\frac{3}{4}$ for 250 feet span, and to $5\frac{3}{4}$ tons for 460 feet. The Author then proceeds to consider the ultimate effect of repeated strains without shocks, such as are produced by a passing train, and explains why he thinks Wohler's results on axles to be applicable to girders. The rules he deduces are the following:

1. Fracture occurs sooner, *i.e.* through a less strain per square inch, if a load is removed and frequently reimposed, than if the same load is permanent.

2. The less the strain produced by the moving load, the oftener must it be removed and brought on again before producing fracture, *i.e.* the longer will the girder last.

3. The number of separate loadings required to produce fracture is greater, in the same ratio as the maximum strain is greater.

4. If the maximum strain of a moving load never reaches a certain limit (which Launhardt calls "work-strength"), fracture will never occur.

5. This "work-strength" is larger if the strain produced by the permanent load is larger.

Wohler's experiments, which lasted from 1859 to 1870, were continued by Professor Spangenberg at Berlin up to the year 1873, and the above laws were confirmed. The Author adds tables showing the calculated strains and those resulting from experiments, the differences being but slight. The Author also attempts to establish a mathematical curve for the "work-strength," and compares it with others calculated by Gerber

and Launhardt. He next considers the effects of repeated moving loads on the resistance to compression, the previous work having applied to tension only. The experiments made in this respect are hardly sufficiently numerous; but with the results arrived at, the effects of moving loads often repeated but without concussions or blows are gone into, the cases of tension only, compression only, tension greater than compression, and compression greater than tension, being all separately considered. Having established rules for these cases, the Author discusses the effect of repeated blows, which he compares to a weight equal to that on the driving wheels of a heavy engine falling through a height h; he again, however, repeats that the experiments are as yet incomplete, and do not prove that the effects of the shocks of an engine are really similar to those of a weight falling on the girder. An investigation of these effects on a girder already strained by the moving (but not striking) load, as described in the previous section, then follows, and all the cases of compression and tension, and both, are separately considered, the conclusion being that the actual strain which obtains by the rapid passing of a heavy engine is greater than the strain resulting from the calculation of the moving load alone in the proportion of about 1.3 to 1.0, while it only affects the permanent load in small spans.

The extreme proof-strains habitually placed on girder bridges to test them are condemned; and an abstract is given of the methods hitherto pursued by Gerber, Launhardt, and others for calculating the effects of moving or "striking" loads.

THE ATMOSPHERE CONSIDERED IN ITS GEOLOGICAL RELATIONS.

By EDWARD T. HARDMAN, F.C.S., H.M. Geological Survey of Ireland.

From "The Quarterly Journal of Science."

The gaseous envelope which surrounds our globe plays a very considerable part in the chemical changes ever going on in rock formations, whether actually at the surface—as in what is called the "weathering" of rocks—or in the less apparent, but perhaps more powerful, action carried on at greater depths, whither the atmospheric gases are conveyed by the action of percolating water. It has been shown by the experiments of Prof. Rogers, as well as by those of Bischof and others, that perfectly pure water has a very appreciable solvent effect on rocks and minerals; and that its power is immensely augmented, and capability to produce even more momentous alterations in the form of chemical decomposition added, when it is charged with carbonic acid, oxygen, nitric acid, and other matters derived directly or indirectly from the atmosphere.

While on the one hand, the influence of the atmosphere disintegrates and destroys rock-masses, on the other it is mighty in building them up. Without the small percentage of carbonic acid contained in air—a quantity relatively minute, but in the aggregate enormous—there could be no vegetation. The vegetable kingdom, which obtains its supplies of carbon from those insignificant traces, would be wanting, and there could be none of the coal-beds which form such important members of our rock-formations. This is a direct and palpable case. But if we consider the immense masses of limestones which have been accumulated from those of the Laurentian period, and for aught we know before it, up to the coral reefs of the present day, and which must owe their being indirectly to carbonic acid of former atmospheres, we shall have some idea of the stupendous results attained by very small means, provided time enough be granted.

A drop of rain water absorbs a trace of carbonic acid from the atmosphere, falls on a rock containing lime in some

form, dissolves the lime as bicarbonate, carries it down to the ocean, and finally gives it up to become part of the skeleton of a coral or mollusc, which in its turn may form a portion of an immense mass of limestone rock.

The atmosphere mainly consists of a mechanical mixture of oxygen and nitrogen; these, however, bear to each other an almost constant proportion, any variations being extremely minute. The composition by volume is found to be as follows:

Oxygen	20.80
Nitrogen	79.20

Carbonic acid,* 3 vols. to 10 vols. in 10,000 vols.

Ammonia, a trace; 0.1 to 135 vols. in 1,000,000.

Nitric and sulphuric acids, traces occasionally.

The respective amounts of oxygen and nitrogen do not vary to the extent of as much as 1 per cent., even in exceptional cases. Regnault's analyses of samples of air collected in various parts of the globe gave very close results, the percentage of oxygen being to all intents and purposes identical, viz., 20.9 per cent. Air collected by Sir James Ross in the Arctic Regions did not differ in this respect from that collected at Paris, or at Ecuador in South America; the very slight differences that have been observed not exceeding those noticed in air collected at the same place at different times: and the same results have been obtained from air collected at the summit of Mont Blanc, and even from that taken at a height of 21,000 feet by Gay-Lussac during a balloon ascent. There is, therefore, a marked uniformity in aerial mixture under all circumstances.†

It has not yet been explained how it is that a mere mechanical mixture should have this constant composition, but it is certain that the gases are not chemically combined—

1. Because the proportion of the constituents bear no simple relation to the atomic or combining weights of those elements.
2. When they are mixed in the proper quantities there is no contraction, nor is there any evolution of heat, and the mixture acts in every way as air.
3. Water through which air is passed dissolves the two gases in very different proportions to those in which they are associated, the oxygen being very soluble, while the nitrogen is not taken up to any notable extent.

CARBONIC ACID.

Although the bulk of the atmosphere is made up of the two gases just referred to, these do not take so active shares in geological matters as the almost infinitesimal trace of carbonic acid present. This, then, deserves the place of honor in the following pages, and it will be seen that there is a great deal to be said about it. We shall, therefore, defer the consideration of the behaviour of the other constituents for a little while.

The amount of carbonic acid ranges from about 3 to 10 volumes in 10,000 volumes of air, and the proportion varies between these limits in different localities, owing to many modifying causes. In the neighborhood of towns or cities it will be much increased by the combustion of fuel, the exhalations of animal life, and the decay of organic matters. In the vicinity of large forests, swamps, and fens, vegetable decay will also augment it, though at the same time the living vegetation there will help to reabsorb it, or, to speak exactly, to decompose it. Near volcanoes the air will be more or less impregnated with it; and from many mineral springs, and subterranean caves and fissures, a very considerable quantity of this gas is discharged into the atmosphere. The percentage of carbonic acid also varies slightly between day and night.

GEOLOGICAL EFFECTS.

So small a trace as even 10 in 10,000 —taking the maximum at only 0.1 per cent.—certainly does not at first sight seem capable of performing any very great geological work; but we must

* Strictly carbonic anhydride; but I shall use the less scientific but more familiar term in this paper to designate it, in accordance with geological custom as regards this gas. Indeed, in its geological relations it may be regarded as a true acid when dissolved in water.

† From some recent observations, by Boussingault and Miller, it would appear the amount of oxygen slightly differs at various heights. Mendeleeff thinks Gay Lussac's results are probably incorrect (*Bull. Soc. Chim.* [2], xxv., 394). However, we have hardly decisive information yet on this point.

recollect that the vast quantities of existing vegetation are entirely dependent on the carbon they obtain from the atmosphere, and the decay of vegetation, and consequent liberation of carbonic acid, has a very powerful effect in the alteration or solution of rocks. However, the direct action of atmospheric carbonic acid on rocks—both as a destructive and as a recuperative agent—must be anything but small, even at the present day. As to the latter, it is only necessary to refer to the immense coral reefs now being formed, while the widespread deposits of ooze and mud over the floors of the Atlantic and Pacific are largely due to carbonic acid entrapped by rain water and carried down into the ocean. On the one hand, the carbonate of lime previously conveyed by river waters is held in solution, and kept in a fit state for assimilation by marine organisms. On the other, the dead shells while sinking through great depths are attacked, forming, as Sir Wyville Thomson tells us, if the depth is not sufficient to give time for complete decomposition, a calcareous ooze; at greater depths the deep sea muds.* Thus a very great amount of the carbonate of lime in the ocean owes its existence entirely to atmospheric carbonic acid, either from the direct action on calcareous rocks, whether old limestones or silicates,—or indirectly through a series of changes whereby carbonate of soda would be produced, and this being brought into contact with the chloride of lime so abundant in the ocean, carbonate of lime would result. There can be no question but that such effects are going on extensively day by day.

INFLUENCE OF VEGETATION.

If we follow the series of rock-metamorphisms, due to the simple absorption of carbonic acid by a plant, the result will be seen to be more than interesting. The carbon is assimilated by the plant, an equivalent of oxygen being exhaled. The plant dies, and may become either a part of a coal bed or may be separately imbedded amongst layers of sediment of some kind. Slow decomposition will now set in, sooner or later, and, if there be a reducible compound near it, chemical changes result. Say the strata contains sulphate of iron: this is reduced to sulphide, commonly known as iron pyrites, a very common mineral in coal seams—as colliery owners know too well—or in other strata where plants abound. The reduction is effected by the carbon of the plant abstracting the oxygen from the sulphate, and the resulting carbonic acid either is taken up by percolating water, and penetrates farther into the heart of the rock, effecting new changes, and producing carbonates, or it finds its way to the surface through some crevice or by the aid of a mineral spring, and once more mingles with the atmosphere, to be perhaps again absorbed by vegetation, and pass through a round of similar changes afresh. Carbonic acid exhalations are very abundant at the surface of the earth, and are in great part ascribable to the oxidation or decay of organic matter which in the first instance derived its carbon from the atmosphere.

The above case shows the result of slow decomposition at great depths; but similar effects are induced by the decay of organic matter near or at the surface. In swampy grounds, lagoons and deltas, such as those of the Mississippi and the Sunderbunds, the decay of organic matter must exercise a very powerful influence on the chemistry of the soils, rocks and sediments with which the water charged with the compounds formed during the process of rotting comes in contact. Peroxides, such as those of iron and manganese, will be reduced to the proto state, and will be rendered soluble and carried away in solution, to be after a while re-oxidized and deposited in such masses as to be worth working as ores. Silicates of soda, lime and magnesia will be decomposed, and removed as carbonates; and sulphates, which are usually present in most waters, will be reduced first to sulphides, and eventually decomposed with evolution of sulphuretted hydrogen. Such a process as this may be observed every autumn in the North of Ireland during the maceration of the flax plant, which is placed in pits filled with water, and, being allowed to remain for some weeks, the softer tissues are rotted away, leaving the fibers fit for

* It now appears, however, that a considerable portion of these muds is derived from the gradual disintegration of pumice and other volcanic *débris* very widely spread over the sea-bottom. See Mr. John Murray's paper on the "Distribution of Volcanic Débris" (Proc. Roy. Soc Edinb.). The result is still due, however, to the action of carbonic acid dissolved in the ocean.

manufacture. The stench of sulphuretted hydrogen from the decomposing flax is almost unbearable. Having analyzed the mud which subsides to the bottom of the flax-pits, I find that the reducing power of the rotting tissues are as described above. The clay in which the pits are sunk contains nearly all the iron present in the ferric condition when not subject to the action of the plants, but in the mud from the bottom there are only proto-compounds, the iron mostly as carbonate. Nor is there a trace of peroxide of iron in the flax-water, but, on the contrary, plenty of ferrous iron.

Clay-Ironstone. — After this fashion must have been formed the clay-ironstones of the coal-measures. The great swampy estuaries of that period may be regarded as gigantic flax-pits; and the rotting vegetation not only altered other salts and compounds of iron to carbonates, but prevented the oxidation of such carbonate of iron as might have been carried down in solution, until in course of time it also was precipitated along with the clayey sediments.

During such changes near the surface a very large proportion of carbonic acid is returned to the atmosphere. And that there must be, and always has been, this constant circulation of carbon between the earth and the atmosphere is self-evident. What time it originated must be beyond our ken, but, so far back as we have any knowledge of, there are evidences in the rocks of vegetable or animal life. And the decomposition of such carbonaceous matters, whether at the surface, immediately after death, or whilst buried under a depth of strata,—as in the case of coal-seams,—has always yielded carbonic acid to the atmosphere. At the same time the carbon returned in this way falls far short of what has been abstracted. But, as Bischof points out, the carbon acts as a carrier of oxygen between the mineral kingdom and the air.

FORMERLY GREATER ABUNDANCE OF ATMOSPHERIC CARBONIC ACID.

It has long been considered probable that in remote ages the proportion of carbonic acid was greater than it now is, more especially during the Carboniferous Period. The remarkable luxuriance of vegetation of a tropical *facies* during that era, in every part of the globe,—even the polar regions,—indicates a very warm climate universally, and it is also thought to imply a much larger supply of carbonic acid than is now noticeable in the atmosphere. The rarity of warm-blooded animals has been pointed to as a corroboration of this view; but strictly this is only negative evidence, the absence of fossil forms affording no proof as to the non-existence in by-gone time of animals of any particular type. However, a very curious fact bearing on the question has resulted from Prof. Tyndall's researches on radiant heat. It appears that a very small addition of carbonic acid to air renders it absorptive and retentive of radiant heat, and a slight increase in the percentage of carbonic acid in the atmosphere would have a very distinct result. The visible rays of the sun could pass through the atmosphere to the earth; but the radiant heat from the earth, instead of being dissipated into space, would be imprisoned by the atmosphere, which would thus form a warm envelope around the earth, converting it in fact into an immense greenhouse. The glass roof of a conservatory acts in precisely the same way: it permits the solar rays to penetrate freely, but absorbs and cuts off the escape of the radiant heat, and the interior temperature is thereby rendered tropical. Granting, then, the former abundance of carbonic acid, the extreme richness of the carboniferous vegetation, its tropical character and wide distribution are very fairly accounted for. I shall show presently that there are other grounds for the supposition that the carbonic acid is now much less than it has been in these far back periods; nor is it to be considered that it reached its maximum even in the carboniferous age. It is true that the earlier formations afford nothing like such a superabundance of fossil plants; but this has been well accounted for by Dr. Sterry Hunt. He has shown that the vast amount of chemical action that has taken place in the reduction and accumulation of the metalliferous deposits of the older Palæozoic rocks will readily account for the scarcity of fossil vegetation in those rocks. To the decay of plants and the reducing action of the resulting carbonic acid those deposits must be in great measure attributed; and

their existence proves that an abundant flora flourished. The manner in which this chemical action takes place will be explained further on. I shall just quote Dr. Hunt's words on this point:—"Where are the evidences of the organic material which was required to produce the vast beds of iron-ore found in the ancient crystalline rocks. I answer that the organic matter was, in most cases, entirely consumed in producing these great results, and that it was the large proportion of iron diffused in the soils and waters of these early times which not only rendered possible the accumulation of such great beds of ore, but oxidized and destroyed the organic matters which in later ages appear in coals, lignites, pyroschists, and bitumens. Some of the carbon of these early times is, however, still preserved as graphite, and it would be possible to calculate how much carbonaceous material was consumed in the formation of the great iron-ore beds of the older rocks, and to determine of how much coal or lignite they are the equivalents." *

If we also reflect that the enormous quantities of lime-stones which are found in the older formations have been largely dependent on the carbonic acid of the atmosphere—in effect, the further we retrograde towards a primitive condition of things the more directly such carbonic acid must have come into requisition for such purposes, as there would be the less of it stored up in rocks, to be re-utilized as at the present day, when much of the carbonate of lime in waters is obtained by the disintegration of pre-existing lime-stones—and remember also the carbon that was required for the teeming animal life of ancient times, we shall see that there could have been no lack of carbonic acid; and it becomes a matter of small difficulty to accept the theory that a retrogressively greater proportion of carbonic acid gradually leads back to a primitive atmosphere in which that gas —as well as perhaps other gaseous acids, such as hydrochloric acid—was very abundant.

In regard to this question as to the increase or decrease of carbonic acid, a variety of very interesting points suggest themselves, and the facts almost altogether seem to range themselves on the side of a progressive decrease of carbonic acid. It seems certain that the amount of carbon stored up in the recesses of the earth very far exceeds that of the entire quantity combined as carbonic acid in the air. It is true that Liebig supposed the carbon so combined, which he calculated to reach 2800 billions of pounds, equal to about 1,250,-000,000,000 tons,—figures and tons will probably aid in a better conception of this enormous weight,—to be far in excess of all the carbon stored up in coal-beds, and in plants on and in the globe. But this will hardly be subscribed to when we remember that the coal of the British Isles alone, as estimated by the late Coal Commission, is about 195,000,-000,000 tons (I have added about a third for waste, &c., deducted in the original estimate). The carbon in this will weigh about 146,000,000,000 tons, taking an average of eighty per cent. But this was only calculated for coals fit for use, of not less than one foot thickness, lying at no greater depth than 4000 feet. Now if we include all the coal of inferior quality, of less than one foot thick, and at greater depths than 4000 feet, and then throw into the balance the enormous supplies of coal of the rest of the world and of the older and newer formations, not to speak of the highly carbonaceous shales, slates, schists, and clay ironstones, I think—even taking only this branch of the subject—we should rather be led to agree with Bischof, who, on the other hand, calculates that there is at least 6620 times as much carbon in the earth as Liebig has estimated for the atmosphere;* and Bischof's calculation is based on the very moderate assumption that the average proportion of carbon in all rocks is at least 0.1 per cent., which he considers—and no doubt justly—must fall far short of the real amount. This being so, it would certainly appear that there has been more carbon accumulated in the earth than has been restored to the atmosphere by decomposition, and that therefore the quantity of carbonic acid in the air has been gradually lessening from remote periods up to the present time. This

* "On the Origin of Metalliferous Deposits."—Chem. and Geological Essays, p. 229.

* Bischof, Chem. Geology, vol. i., p. 704. Dr. Sterry Hunt has also estimated the amount of carbon secreted in the earth as far beyond that contained in the present atmosphere,

appears anything but improbable, remembering the arguments already noticed in favor of the supposed highly carbonated atmosphere of the carboniferous period; and although the calculations leading to such a conclusion are necessarily based on very imperfect data, it may be safely affirmed, at least, that such a state of affairs is not only possible, but probable.

In these calculations we are not only to consider the carbon of the vegetable kingdom, for it will be obvious that any *animal* carbon which may remain in rocks is also more or less directly derived from the carbonic acid of the atmosphere. Taking the extreme case of the *Carnivora*, it is clear that they must ultimately depend on the air for their supplies of flesh-forming material. Say a tiger dines off a cow; the carbon and nitrogen of her flesh have been obtained from vegetation, which in turn extracted them from the air; so that we have a kind of physiological "House that Jack built." "This is the Tiger that ate the Cow that devoured the Grass that absorbed the Carbon," &c. Viewed in this way it seems that "living on air" is a more substantial kind of existence than has usually been supposed.

Now this which is true of the higher animals applies equally with regard to lower forms. There will be a vegetarian somewhere to fall a prey to a carnivorous marauder, who in his turn may be the victim of a stronger individual; and the successive appropriations may go through any number of steps. Thus the carbon and nitrogen of forms of animal life now fossil have been also derived from the atmosphere. We do not find much, if indeed any, of this carbon in its original form now, or directly traceable to animal agency, because highly nitrogenous organic substances decay very rapidly, but it is not unlikely that their results are to be seen in carbonaceous and bituminous shales, and oleiferous rocks such as those in the neighborhood of petroleum springs; for, as Dr. Sterry Hunt remarks, since animal tissues contain the elements of cellulose, plus water and ammonia, they may give rise to similar hydrocarbonaceous bodies to those derived from vegetable substances.*

In many cases, also, the decomposition of these animal tissues would result in the formation of carbonates, so that on the whole there must be, through this source, a vast quantity of carbon—originally drawn from the air—locked up in the crust of the earth. And to all must be added the immense amount of carbon combined as carbonate of lime due to the direct solvent action of atmospheric water on calcareous rocks and minerals. If we add all this to the vegetable carbon already considered, there can hardly be a question but that the amount of carbon abstracted from the atmosphere and hidden away in our globe very, very far, exceeds the proportion present in the air of this age. If this be granted—and I cannot see any possible evasion of it—we must admit that the more ancient atmospheres contained far more carbonic acid than that which now envelopes us, and must renounce the doctrine of Uniformity in this connection at any rate.

ORIGIN OF CARBONIC ACID.

Having got so far, we are naturally led to inquire as to the origin of the carbonic acid in the first instance. Carbon is so thoroughly associated in our minds with organic matter, or in fact with *life*, that it is difficult to conceive the possibility of its existence in an azoic world, and the difficulty is aggravated by the recollection that the earth must have been at the beginning in a state of incandescence, not to go further and say a gaseous condition. However, under the influence of extreme heat, many elements are isolated which at lower degrees of temperature—but still very great—combine and form chemical compounds. For example, hydrogen and oxygen at a high temperature unite to form water, but at a still higher are again dissociated, and we know that hydrogen exists in a state of incandescence, not combustion, in the sun's photosphere.† Similarly free carbon might have been one of the gaseous constituents of the earth in its nebulous phase,‡ and as the temperature lowered might have been consumed, or united with oxygen, and gone to form part of the primeval atmosphere. In

* Chem. and Geol. Essays. "On Bitumens and Pyroschists," p. 179.

† Prof. Henry Draper has just announced the discovery of oxygen in the sun. *Nature*, August 30, 1874.

‡ According to Mr J. Lawrence Smith, carbon in the gaseous form is spectroscopically manifest in the attenuated matter of comets. *Am. Journ. Sci.*, June, 1876.

this way all the carbon now in the crust of the earth would necessarily have been at first confined to the atmosphere. Then when rains began to fall, the carbonic acid, being carried down upon the earth, would soon decompose the silicates which must have resulted from the cooling down of the original heated mass; carbonates would be formed and carried down into the primitive oceans, and clayey residues would be left behind.

In course of time, when vegetable and animal life had made their *début*, the withdrawal of the carbonic acid from the air must have proceeded much more rapidly, and the atmosphere gradually cleared to such a condition as to permit of the existence of air-breathing animals. It may be here remarked that the very gradual introduction, in more recent periods, of warm-blooded beings, would also coincide with the hypothesis of the originally highly mephitic state of the atmosphere.

CARBONIC ACID NOW INCREASING OR DECREASING?

An important question now arises—Is the amount of carbonic acid increasing or decreasing, and what may the result be in either case? To begin with the last part of the question:—Any considerable difference one way or the other must result in a diminution of animal life: in its higher forms in the former event, in all divisions in the latter. Beyond a certain proportion very little above the ordinary standard—at most ten times, equal to about five vols. in 1000,* or 0.5 per cent!—carbonic acid in air becomes a deadly poison to all warm-blooded animals. On the other hand, a diminution in the percentage of carbonic acid would tell even more severely. Vegetable life would languish, graminivorous animals would eventually have nothing to eat, and, finally, the Carnivora, being obliged to prey upon each other, would of course become extinct. And this would be applicable to all divisions of the animal kingdom. The result would be a completely barren and desolate planet, perhaps in some degree resembling the moon. Doubtless that planet has passed through phases of existence alike to those which have obtained upon the earth; and Mr. Proctor† is of opinion that the moon certainly had originally an atmosphere, which is now either altogether absent or is attenuated to an extreme degree. It can well be imagined that this result, and its consequent azoic addition, has been brought about by some such absorption of the constituents of the moon's atmosphere as that which I have endeavored to sketch out above as regards the earth.

PROBABLE WITHDRAWAL OF OXYGEN.—It may seem a little paradoxical that such dire effects would more immediately follow the withdrawal of a poisonous gas, and that the latter is on the whole more important to the continuance of life than oxygen gas, which is almost inseparable from our ideas of existence; but it is undeniable that such would be the case. The blood requires to be oxygenated, but in the absence of carbon there would be no blood at all. All this leads us to another point. The disappearance of carbonic acid must be followed after a period by the withdrawal of oxygen itself. It would gradually be carried by water into the interior of the earth, from which it could make no return, for it would be seized upon by compounds capable of oxidation, and its retreat in the form of carbonic acid would have been cut off.

As to the first part of the question, however, we have as yet no data for its solution. There are several means by which carbonic acid is supplied to the air, and many by which it is removed; but we are not in a position to determine on which side is the predominance, or whether there is at present a balance of power. The principal sources of increase are

1. Volcanic and other subterranean exhalations.
2. Respiration of animals.
3. Combustion of fuel, &c.

Respecting this last it should be pointed out that we are now restoring to the atmosphere some of the vast quantities of carbonic acid abstracted from it during the Carboniferous period, and imprisoned for ages in the interior of the earth in the forms of coal and clay-ironstone. Perchance by the time we have made an end of our supplies of coal a

* Watts, Chem. Dict., 1862, vol. i., p. 438.

† Quart. Journ. Science, July, 1874. "On the Past History of our Moon."

very sensible difference will have been effected in our atmosphere.

The absorption of the carbonic acid is brought about thus:

1. By vegetation, as already explained.
2. By the agency of marine organisms which secrete carbonate of lime.
3. By the direct action of atmospheric carbonic acid upon rocks, resulting in the formation of carbonates.

How far these antagonistic processes check each other cannot be conjectured. In order to arrive at any conclusion on the matter we should require to compare trustworthy analyses of air taken at frequent intervals during some thousands of years at least. We have yet no recorded analyses of it older than forty or fifty years. Probably in the remote future information will have been accumulated sufficiently to allow of the solution of the problem; and perhaps in those far distant times a Royal Commission, or some such form of Public Inquiry, will be solemnly convened to deliberate as to the possible duration of "Our Carbonic Acid Supplies." But should a necessity ever arise, it is comforting to reflect that it is not likely to occur until some ages after the traveled New Zealander has been gathered to his fathers, and even the very sites of Auckland and Otago perhaps long a subject of curious speculation amongst Central African *savants*. I say it is comforting to take this to heart in these days of sensational cosmogony, when one day we are threatened with destruction from the sweep of a comet's tail, and the next an unfavorable eruption of sun-spots may entail unheard-of miseries upon us. All the information we are in possession of goes to show that the trifling changes that are now observed in the condition of the atmosphere would perhaps require a continuance throughout many millions of years before making themselves disagreeably apparent.

GEOLOGICAL INFLUENCE OF OXYGEN.

This comes next in importance as a geological agent.* I have dwelt first upon the results wrought by the carbonic acid, because the work done by it is immensely greater in proportion to its amount. But oxygen also has its mission. Percolating the rocks, dissolved in rain-water, which is able to absorb a very large quantity of it, it quickly reacts on all oxidizable substances. Carbonates and proto-salts are converted to peroxides; sulphides are changed in sulphates, and sometimes this is accompanied by the production of double salts, such as alums. A familiar instance may be referred to as occurring in the spoil banks of coal-pits, where quantities of aluminous shales, with refuse coal containing iron pyrites, are heaped up together and exposed to the influence of the weather. The oxidation of the iron pyrites results in sulphate of iron, and the sulphuric acid so formed—reacting on the alumina, potash, etc., of the shales—forms a more or less complex alum, which may be observed in small stellate crystals between the laminæ of the shales. Alum slates and earths are very common, and all owe their origin to the oxidation of iron pyrites, or some other sulphide, under circumstances akin the above.

ORES AND METALLIFEROUS DEPOSITS.

The peroxides of iron and manganese are of considerable importance, both commercially and from a scientific point of view. In many cases the formation may be traced directly to the action of atmospheric oxygen. In other instances this action is but veiled by a series of complications. Many valuable deposits of iron and manganese are formed in cavities of rocks through the means of water containing carbonic acid and oxygen. The first dissolves the minerals as bicarbonates; then, the excess of carbonic acid escaping as opportunity permits in open fissures, they are oxidized, and deposited at once in an insoluble form, while such other carbonates as happen to be in solution, and which—like lime, magnesia, and the alkalies—have a stronger affinity for carbonic acid than for oxygen, are carried away.

By such a process as this, immense beds of limonite have been deposited, and the liberated carbonic acid restored to the atmosphere. Bog iron-ores and the well-known lake iron-ore deposits of Sweden, are cases in point. Some of these deposits are assisted by organic agency, some of the Diatomaceæ—*Gal-*

*The amount of oxygen in the atmosphere is about two trillions of pounds (Bischof, *op. cit.*, I., 204), equal to about 892,857,000,000,000 tons.

lionella in particular—being very active in this way ; but they are only accessory aids, the real work being due to chemical reactions between carbonic acid, oxygen, and soils or rocks. The extensive beds of hematite associated with the Antrim basalts, are unquestionably lake-deposits, as Prof. Hull has suggested, and must be due also to the reciprocal chemical action of the carbonic acid and oxygen from the atmosphere. These beds are now intercalated between the sheets of basalt, and sometimes reach a considerable thickness, consisting of beds of rich ore, poorer ore, and "lithomarge," which is a highly ferruginous clay. Prof. Hull considers that all these were deposited in a large lake or series of lakes. Assuming this, the *modus operandi* was probably this : The highly ferruginous basalt forming the shores of these lakes being subject to the action of atmospheric water, the iron existing as proto-silicate in the augitic rock, was dissolved out as carbonate and carried into the lake. The excess of carbonic acid then escaping, oxidation ensued, as in the case already referred to, and the iron was precipitated as a hydrated peroxide. At the same time fine sedimentary aluminous matter was also carried down and deposited, and, according as the amount of this was greater or less, a bed of lithomarge or workable ore was laid down. A fresh volcanic outburst eventually taking place, the lakes were covered in, and the ore bed preserved from denudation.

The ore must have been precipitated in the hydrated state, and the water of combination was doubtless afterwards given off spontaneously, in the same way as by hydrate of alumina and the hydrated forms of silica. There is indeed considerable analogy between the hematites and the colloid forms of quartz. It is only necessary to compare these pisolitic and botryoidal iron-ores with the calcedonys to see this, and the comparison would be in favor of the aqueous origin of such iron-ores were fresh proof needed.

It will be obvious that the reactions sketched out above with regard to iron-ores and compounds, applies equally to all other minerals capable of being oxidized or reduced. Copper pyrites, for instance, is often oxidized to sulphate, and the carbonate altered to oxide just in the same manner.

ANTAGONISTIC ACTION OF CARBONIC ACID AND OXYGEN.

Clearly, then, the carbon and oxygen derived from the atmosphere sustain antagonistic parts in their action on rocks and minerals. They are perpetually warring the one against the other, and thus keeping a circulation between the earth and the air. The carbon reduces the oxides whenever it encounters them, and the oxygen replaces the carbonic acid of carbonates with the same inveteracy. The combined effects of these elements in geological transformations is extraordinary when we come to reflect on it. Regarded from an utilitarian point of view, to them we owe probably every metalliferous deposit of value in the world. I have shown how a highly ferruginous rock, such as basalt, containing proto-salts of iron, which are soluble in carbonic acid, might be acted on directly by that acid from the atmosphere. But there are cases where insoluble compounds of iron in small quantity, locked up in rocks, are, by the reducing action of the carbon of decaying vegetation, liberated, and finally accumulated in such quantities as to be of commercial value. Soils and clays contain small portions of per-oxide of iron, which is insoluble. The decay of vegetation or other organic matter robs this of oxygen, giving rise to carbonic acid. The resulting *protoxide* is soluble in water containing carbonic acid, or other organic acids, and is carried down into lakes or fissures, where, again absorbing oxygen, it forms beds or veins of hematite.

While insoluble oxides are rendered soluble and allowed to accumulate in this way, soluble sulphates are reduced to insoluble sulphides,—iron pyrites, copper pyrites, zinc blende, galena, &c., —and, as Sterry Hunt puts it, "removed from the terrestrial circulation," for a time at least. Such are the processes to which many metalliferous deposits are due.

Another result of the opposition of these two atmospheric gases is the defertilizing of soils, and consequent failure of vegetation. An ordinary fertile natural soil contains, amongst other things, silicates of alumina, lime, potash, and

soda, with some peroxide of iron. The silicates of lime and soda will be decomposed by carbonic acid, and the bases removed as corbonates. The potash silicate is also decomposed, and a part of the potash removed by aquatic plants under favorable circumstances, in marshy places, &c.,—conditions under which the vegetation of the Coal era flourished,—and the ferric oxide is reduced to the ferrous state by the deoxidizing influence of rotting vegetation. This having occurred, the roots of plants are for a time debarred from any access of oxygen, for any that permeates the soil will be immediately siezed on by as much of the proto-compound of iron as has not been carried off in its soluble state, and this is again converted to the higher condition; and these changes continue until they result in the total barrenness of the soil and its ultimate conversion into a hydrous silicate of alumina, almost entirely free from iron, such as we are acquainted with in the fire-clays of the coal-measures—those ancient soils on which the vegetation now forming our coal-seams once grew.*

AMMONIA AND ITS COMPOUNDS.

Ammonia exists in the air chiefly in the form of carbonate of ammonia, but the quantity, whilst always small, appears to vary greatly, and it is not positively ascertained whether the variation is to be ascribed to natural causes, or ought to be referred to the difficulty of accurate analysis when such small quantities have to be dealt with. It is quite possible, however, that the variability is natural. The minimum recorded is 0.1 part of carbonate of ammonium in one million of air; the maximum is 135 parts.† Rain-water, hail, snow, and dew contain appreciable quantities of ammoniacal salts, and in rain from thunder-showers the ammonia is combined as nitrate, the effect of the electric discharge being to oxidize a portion of the nitrogen of the air to to nitric acid.‡

The atmospheric ammonia is not without its effect on vegetation. It is certain that plants grown in air perfectly free from ammonia never flourish to the same extent as those surrounded by an atmosphere containing some of it; and the experiments of Boussingault, Lawes and Gilbert—borne out as they are by those of Stockhart, Peters and Sachs, and lately by the very conclusive researches of Shlœsing* and A. Mayer†—show that at least a considerable part of, if not all, the nitrogen of plants is derived from this source. Now the geological connection of this is at once plain, for the decomposition of nitrogenous matter such as plants, in rocks, may lead partly to the formation of nitrates, or, by the evolution of nitrogen and ammonia in volcanic regions, give rise to other minerals, as I shall show presently.

Occasionally the ammonia is absorbed directly from the air by surface mineral matter, as in the case of the volcanic earth of the Solfatara of Puzzuoli. S. de Luca‡ tells us that this contains a quantity of sulphur and arsenic which under the influence of air and moisture form acids, and at once, combine with the atmospheric ammonia. But it is to the decay of vegetation that the vast majority of the nitrogen compounds which are met with, either as minerals or as volcanic emanations, are due, and in whatsver state the nitrogen was originally absorbed—whether in the free state or as ammonia—it cannot be doubted that all the nitrogen compounds contained in the earth, as it now exists, are traceable entirely to past and present atmospheres.

The nitrogenous compounds so obtained are themselves subject to an endless variety of changes, in which the gases already described bear no unimportant parts—reducing and oxidizing; and these changes, or the effect of heat, may result in a renewed evolution of ammonia to the atmosphere.

Under such circumstances occasionally the ammonia, instead of escaping freely

* It is obvious that this only applies to natural soils, since the agriculturist by breaking up the ground affords a supply of oxygen much in excess of what is absorbed by the oxidizable matter present.

† Watts, Chem. Dict., p. 439. P. Truchot finds that the amount of ammonia varies with the altitude. At Clermont-Ferrand, 395 metres above sea-level, the quantities were 0.93 m.grm. to 2.79 m.grms. in a cubic metre of air,—according as the day was clear or dull,—whilst at Pic de Sancy, 1884 metres, it amounted to 5.27 and 5.55 m.grms. under the same conditions. Comptes Rendus, lxxvii., 1159—1161.

‡ Liebig found that of seventy-seven specimens of rain-water, seventeen, collected during thunder-storms, contained nitric acid combined with lime and ammonia. Of the remaining sixty but two contained traces of it.—Bischof, *op. cit.*, i., p. 214. According to Bottger, the induction spark passed through moist air gives nitrogen peroxide and ozone, but in dry air gives nitrous fumes.—*Chem. Centr.* (1873), 497. Doubtless similar results follow discharges of natural electricity.

* Comptes Rendus, lxxviii., 1700.

† Deut. Chem. Ges. Ber., vi., 1404–1413, and Landw. Versuchs. Stat., xvii., 329.

‡ Comptes Rendus, lxxx., 674.

into the air, meets with hydrochloric as in the depth of volcanoes, and combining with it is evolved as chloride of ammonium (*sal-ammoniac*), which is condensed on meeting with the cooler external air. This mineral is often met with in large quantity, so much so, indeed, as to be of commercial value. Thus during the eruption of Vesuvius in 1794 great quantities of this salt were evolved, and it was collected by the peasantry; and Hecla in 1845 yielded very profitable supplies of it. In the vapours of the Solfatara, at Puzzuoli, it is also met with, and it is found mixed with sulphur and other matters in the crater of Vulcano, where it is now being largely collected,* and in considerable quantity at Etna. Then the volcanoes of Kutsché and Turfan, in Central Asia, afford such large supplies that it has been a very valuable article of commerce.†

Prof. Judd is at loss to explain the production of those large quantities of sal-ammoniac, unless on Daubeny's supposition that nitrogen under the influence of heat is unusually active; but the matter is readily accounted for thus:—The decomposition of nitrogenous organic matter at all times produces ammonia, but especially so under the influence of heat (a familiar instance in the manufacture of coal-gas). That a sufficiency of such organic matter exists in the rocks through which these volcanoes have burst is undoubted, and the ammonia evolved combines with avidity with the hydrochloric acid‡ also given out in volcanic emanations.

Quite lately a new mineral has been discovered incrusting the recent lava both of Etna and Vesuvius. This is a nitride of iron named "*Siderazote*" by its discoverer, Silvestri,‖ who considers it is due to the decomposition of ammonium chloride by heat in the presence of ferruginous lavas; and although we may not quite accept his theory that the ammonium chloride is formed by the absorption of nitrogen direct from the atmosphere by the lava, it is certain that the nitrogen has been originally drawn from that source. We may fitly conclude this part of the subject with the mention of the native sulphate of ammonium *Mascagnine*, of which it may be said that every constituent could have been obtained from the atmosphere.

* J. W. Judd, "On Volcanoes," Geol. Mag., Dec. 2, vol. ii., p. 113.

† Bischof, *op. cit.*, i., 212—213.

‡ The formation of white fumes of ammonium chloride when a glass rod dipped in ammonia is brought near hydrochloric acid will occur to chemical readers.

‖ "The Occurrence of Nitride of Iron amongst the Fumarole Products of Etna, and its Artificial Preparation." Orazio Silvestri, Gazetta, Chim. Ital., v., 301—307. Pogg. Ann., civii., 165—172.

NITROGEN.

It is obvious that much of what has been said regarding ammonia will apply to nitrogen, but on the whole the latter in its free state appears to have but little influence as a geological agent.

SULPHURIC AND SULPHUROUS ACIDS.

The exceedingly minute traces of these acids make but a slight effect on rocks when compared with the gases already touched upon. That they are not altogether inert may be taken for granted, but both their absorption and re-evolution are of a local nature, being chiefly apparent in the neighborhood of large towns and about volcanic regions. They may be "withdrawn from circulation" as sulphates and sulphides, and be returned in their original state, or decomposed into sulphur or sulphuretted hydrogen.

VARIATIONS OF ATMOSPHERIC PRESSURE.

These cannot but have an appreciable effect on certain classes of geological phenomena. The emanations of gases from the interior of the earth are influenced in some degree. It is well known that explosions in coal-mines sometimes follow a sudden fall of the barometer, which can be well understood on comparing the pressure corresponding to different barometric heights.

Barometer at	28	inches.	Atmospheric pressure	13,70	lbs.
"	29	"	"	14,19	"
"	30	"	"	14,68	"
"	31	"	"	15,17	"

It is usual to refer to the atmospheric pressure as about fifteen pounds on the square inch, but the above table shows that a considerable variation makes itself felt within the barometrical range. This must not only control evolution of gases from coal-seams, but also exhalations from open grottoes and caves, mineral springs both thermal and otherwise, and probably from intermittent active volcanoes, such as Stromboli, where the periodical explosion of gases is an important

phenomenon. With regard to this Mr. Judd says "that the barometrical condition of the atmosphere must exercise a powerful influence on such a series of operations as are seen to be going on within the crater of Stromboli, few, probably, would be bold enough to deny." It appears "that the more violent states of activity . . . . coincide with the winter seasons and stormy weather, and its periods of comparative repose occur during the calms of summer, is established not only by the universal testimony of the inhabitants, but . . . . by the actual observations of many competent authorities." It is hardly necessary to point out that during stormy and wintry weather the barometer is mostly low, while the contrary is the case during summer time and calms.

It is not impossible that similar antagonism between outward and inward pressure may affect the working of many other vents, such as the Solfatara of Naples, and mud-volcanoes, such as those of Sicily, Transylvania, &c.; and that such variations may have no inconsiderable results, both as regards the chemical and cosmical effects of volcanic action.

And now, reviewing the preceding notes, it will be seen what an all-powerful geological agent the atmosphere we breathe is. Without its aid we should know never a stratified formation. The earth would simply form a ball of truly primitive rock, resulting from the cooling down of the original nebulous mass set apart for our globe, the only variation in which primeval and perennial crust being that of the different strata of higher specific gravity towards the interior. We should have no coal, no metalliferous deposits, no rivers or seas, and no rain,—consequently no denudation by "Rain and Rivers,"—for the vapor of water could not ascend into empty space. We should have——but, last and worst of all, there would be no "we." Life would be impossible, and the earth would finally degenerate into a

——"pale-faced moon."

That this is probably her ultimate mission cannot be denied. The only consolation is that owing to her larger size, and therefore slower rate of cooling than the moon, she will have gone through a somewhat more extended geological course. There is undoubtedly a very intimate connection between secular cooling and withdrawal of atmosphere, for the cooler the interior the smaller will be the return of gaseous elements to the surfaces; and probably before Saturn and Jupiter have cooled down to a habitable temperature, the senescent earth will roll through space—cold, void and airless. Sooner or later nothing is more certain than that

——"to this favor she must come."

MAXIMUM STRESSES IN FRAMED BRIDGES.

By Prof. WM. CAIN, A.M., C.E.

Contributed to Van Nostrand's Magazine.

II.

51. The weights just found are in excess of average practice. This is partly because we assumed an engine weighing 84000 lbs. on drivers in space of twelve feet, the total weight of engine and tender, covering fifty feet, being taken at 160000 lbs., whereas a common specification gives the live load as 60000 lbs. on twelve feet, the engine and tender weighing 130000 lbs. The car loads ordinarily assumed are from 2000 to 2240 lbs. per foot. We have also used smaller unit strains than usual for some bridge members. Since the Ashtabula accident it was proposed to the Ohio Legislature to assume for bridge computations a live load of two locomotives and tenders, the locomotives weighing 91200 lbs. on 12½ wheel base, followed by cars weighing 2250 lbs. per foot of track.

In the Keystone Bridge Company's "Album" p. 22, we read; "For main lines of traffic, it is not considered prudent to assume less than 40 tons in a span of twelve feet,—stringers spanning over 12 feet should be sufficiently strong

to carry 1½ tons per foot for each additional foot." (The 2000 lbs. ton is meant.) Considering the fact that engines are built with us weiging 100000 lbs. on 19 feet, it would seem that, for roads that use such engines, the live load assumed, art. 14, is certainly not too great. For secondary lines a less weight might be assumed, if the road is to continue secondary.

Mr. C. Graham Smith, in a paper read before the Liverpool Enginering Society, of which he was President, June 20, 1877, and republished in the "Engineering News," Chicago, says:

"Mr. Benjamin Baker has conclusively proved, in his admirable little work on 'Long Span Railway Bridges' that there are many circumstances, such as badly maintained permanent way, inclined cylinders, and unbalanced portions of the mechanism of locomotives, together with great weight and length of engines, combined with short wheel base, which will at times render the effective load on one axle equivalent to thirty tons . . . .

"With shallow cross girders, oscillations are set up by heavy continuous traffic which will soon shake loose rivets and bolts and perhaps the connections with the main girders . . . .

"Here is an actual example, recorded in the before mentioned 'Long Span Railway Bridges.' The platform of the railway bridge over the Regent's Canal was constructed, owing to local circumstances, with cross girders only 8 inches deep and 14 feet 6 inches span. With a view of compensating as much as possible for want of depth, longitudinal stiffening girders 18 inches deep were placed at a distance of 2 feet 3 inches from the outer edge of each rail; each cross girder was also well secured by tee iron and gusset plates to the main girders. The bridge, notwithstanding that with 15 tons to one axle, it was so designed that the iron should not be strained more than 4 tons per square inch, completely gave away in four years. Mr. Baker attributes the failure to the employment of a 45 ton engine, the wheel base of which was 14 feet; the ends consequently overhung very much, which would greatly assist in producing oscillations and other undesirable consequences."

Similar facts have been recorded in this country, though the use of trucks causes our locomotives to run much steadier than English ones. The use of deep girders is then advisable, and 50 per cent. may be added to the live load of stringers as an additional precaution. Experience, too often costly at that, can alone decide the effect of the impact, &c., caused by a live load. Its effect is usually included by adding some per cent. of the live load to the total load regarded as static.

52. The weight of chords, in table above, is greater than usual perhaps, as it is not generally customary to find the maximum strain in the chords as above. If two opposing trains meet in the center of the span or elsewhere on the span, the strains induced would be greater than given by our formulæ if the center driving wheels of the two locomotives are less than 50 feet distant. The conditions, included in the formula for chords, are that cars may precede and follow engines 50 feet apart, a condition that certainly can be realized in practice. In fact the end panels would be strained nearly as given by our formula, with engines in front as usual.

The maximum chord strains thus found will however be more rarely felt than the max. web strains, for the latter are caused by every passage of the supposed train—engines in front—whilst the former are only felt when the engines are in the midst of a train. Let us conceive the whole live load *uniformly* distributed over the bridge; the total panel weight then would be 35668 lbs., which substitute for P in the formula, art. 39, and make E=*o*. We have,

$$c_n = t_n = \frac{Pl}{2h}(N-n)\ n = 10600\ (N-n)n$$

On computing the various chord strains from this formula and comparing with the *max.* strains previously found, we shall find that we must add 10 per cent. to strains in first two end panels, 9 per cent. for next two panels and 8 and 7 per cent. to the strains in panels next the center, in order that the strains thus found may equal the max. strains.

For the simple trusses just examined, the determination of max. chord strains is simple, but for compound trusses with two or more systems of triangulation, the method is tedious comparatively, and in practice it would be best to ascertain and tabulate for various spans and loads, the percentages to add to the strains resulting from the load regarded as uniformly distributed.

53. *Permissible Strains per Square Inch in Tension and Compression.*—In Van Nostrand's Magazine for Nov. 1877, p. 459, is an article by the writer on this subject. A brief summary of it will be given.

Weyrauch (see "Constructions of Iron and Steel," Chap. XIII) deduces from

Wohler's experiments, by Launhardt's formula, the following value for the safe strain in kilograms per square centimeter $=b'$ to which wrought iron should be subjected in tension.

$$b'=\frac{2100}{n}(1+\tfrac{1}{2}\,\theta)$$

where n=factor of safety, $\theta=\dfrac{\text{min. B}}{\text{max. B}}=\dfrac{\text{minimum strain that piece ever bears}}{\text{maximum strain that piece ever bears}}$

Impact, vibration, &c., such as a live load causes is not included; and I assumed that its effect varied inversely with θ, and wrote empirically, for *the safe strain on wrought iron ties in lbs. per square inch*,

$$b=7500\ (1+\theta) \quad . \quad . \quad (7)$$

Also, the *safe strain on wrought iron columns in lbs. per square inch*,

$$b=\frac{1}{4+\frac{1}{10}\left(\frac{l}{d}\right)}\,\frac{38500}{1+c\left(\frac{l}{r}\right)^2}(1+\theta) \quad . \quad (8)$$

where $c=\frac{1}{36000}$ for pillars with *flat ends*, $c=\frac{2}{36000}$ for *both ends hinged*, and $c=\frac{1}{24000}$ for *one end flat, the other hinged*; l=length of pillar in inches; d=diameter in direction of bending in inches, and r=radius of gyration of cross section about neutral axis in inches. The factor, $\dfrac{38500}{1+c\left(\frac{l}{r}\right)^2}$ is supposed to be the crippling weight of the column. This term is found *not* to be constant for different forms of cross section as "square column," "Phoenix," "American" or "common" column.* It would be proper then to replace 38500 and the values given above or found experimentally for c, by the corresponding terms for the particular cross section as found from experiment.

54. The above formulæ cause b to diminish for web members more rapidly towards the center of the span than Weyrauch's formulæ do. As impact is more hurtful the smaller the member and as the weight of web members diminishes towards the center of the span this appears reasonable. Should we assume that b from impact alone varied with the weight of the web member of a bridge, the result would be somewhat different from the above, since the weight of web members increases pretty regularly from the center to the abutments, whereas θ increases most rapidly at first.

55. For the chords it will be sufficiently near to put

$$\theta=\frac{\text{dead load of bridge}}{\text{total dead and live load}}$$

Thus in the example art. 42 for chords

$$\theta=\frac{336000}{336000+520000}=\frac{336}{856}=.39$$

If the chord strains are determined by supposing the bridge *uniformly loaded*, then θ is correctly determined as above.

56. Since the strain on any web member is equal to the shearing force on that member multiplied by sec. i,

$$\theta=\frac{(\text{min. S})\sec. i}{(\text{max. S})\sec. i}=\frac{\text{min. S}}{\text{max. S}'}$$

for web members.

Then, arts. 26 and 27, and table art. 21 we get

Panel	Shearing Forces		θ
	Max.	Min.	
1	216108	77000	.36
2	181840	59112	.32
3	148960	39836	.27
4	117468	19172	.16
5	87364	— 5380	0
6	58648	—31320	0

As given in the table art. 42.

If the strains on the web members are known, they may be used in place of the corresponding shearing forces, if preferred.

57. We see that for a 200′ span bridge weighing 336000 lbs., that b, for tension, is varied from 7500 lbs. per square inch on counters and middle ties to 10420 lbs. per square inch for lower chords. Extending the formulæ now to other spans, we should similarly find that for spans of 0, 100, 200, 300, 400 feet, b would vary from 7500 lbs. at center on web ties to 7500, 9400, 10400, 11300, 12200 respectively on end ties or lower chords. When $\frac{l}{d}=10$, nearly the same figures

* See *Engineering News* (Chicago), January 31, 1878, for proposed constants in Gordon's formula.

apply to posts. Thus eqs. (7) and (8) give nearly the same value for all values of θ when $\frac{l}{d}=10$.

58. When the engine comes directly on a member, the effect of impact is much greater than for the web members and must be allowed for empirically; thus we have added 50 per cent. to stringers and floor beam loops, the latter because of their small size.

For the floor beams we have supposed M in B$=o$ $\therefore$ $\theta=o$ and $b=7500$.

For wind strains values of b of 1500 for ties and 5000 for struts was used as the conditions assumed are so rarely fulfilled. It may be remarked that nothing has been added to the chords for wind strains, though its effect must be severe on them, causing *inequality* of strain—another reason why the chords should be computed for maximum strains as in art. 40.

59. The above formulæ (7) and (8) may or may not bear the crucial test of practice. It will probably be admitted however that they possess great advantages in properly comparing different forms of trusses of the same span, to which use they will be put in what follows. Empirical rules in ordinary use are wanting in this; they do not recognize Wohler's law—that the minimum strain sufficient for rupture *decreases* as the difference between the extremes of strain to which the piece is liable, *increases*.

The deduction of Launhardt from Wohler's experiments, that b varies with θ is included in the formulæ above; and the coefficient of θ was changed from $\frac{1}{2}$ as given by Weyrauch to 1 to allow empirically for impact.

60. Gerber also deduced formulæ from Wohler's experiments including 50 per cent. added to live load for impact. Formula (7) above agrees very closely with the values *used* in the Mainz bridge by Gerber, though for $\theta=\frac{2}{3}$ to 1 his formula gives much larger values than eq. 7.

When $\theta=1$, impact is supposed null and $b=15000$ lbs. This seems sufficiently large, though Gerber gives in his Mainz bridge and later formulæ, 22760 lbs. per square inch.

61. The variable factor of safety for posts, $\frac{1}{4+\frac{1}{10}\frac{l}{d}}$ is used to give values for a 200 feet span in accordance with the recommendations and usage of American engineers.

No formulæ for wood is given, as no experiments have been made after Wohler's manner upon it.

62. The compression members in the table art. 42 were supposed hollow cylindrical and of wrought iron. Therefore in eq. (8), $r=\frac{d}{4}\sqrt{2}$. The end upper chord panels were regarded as "flat at one end, hinged at the other;" the other panel lengths as "flat at both ends." The braces were regarded as "hinged at both ends."

The panel length assumed may not be the most economical. It is only by computing the whole weight of the bridge for different panel lengths that the proper panel length can be determined. The most economical height of truss will be considered later.

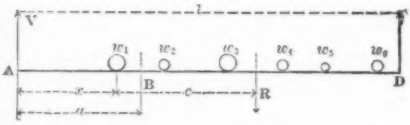
63. The following table of "crippling weights" may prove a convenience:

(*See Table on following page.*)

64. *Maximum Chord Strains due to any number of equal or unequal weights placed at fixed distances apart.*

Let $w_1, w_2 \ldots$ at fixed distances apart be placed on the girder AD, of span l. Let $R=w_1+w_2+m=\Sigma w$, be the resultant of $w_1, w_2 \ldots$ in position and magnitude.

FIG. 8*a*.



Call x the distance from A to w_1, C$=$ distance from w_1 to R, $a=$distance from A to the cross section *whose max. moment, as the load moves forward, is required.* We have $Vl=R(l-x-c)$.

1/. *When w_1 and w_2 are on either side of* B, the moment at B is

$$M=Va-w_1(a-x)=\left\{R\left(1-\frac{c}{l}\right)-w_1\right\}a+\left(w_1-R\right)x \quad \ldots\ldots \quad (9)$$

HOLLOW CYLINDRICAL COLUMNS.

$\frac{l}{d}$	Flat Ends. $\frac{38500}{1+\frac{2}{9000}\frac{l^2}{d^2}}$	One end hinged. $\frac{38500}{1+\frac{1}{3000}\frac{l^2}{d^2}}$	Both ends hinged. $\frac{38500}{1+\frac{4}{9000}\frac{l^2}{d^2}}$	$4+\frac{1}{10}\frac{l}{d}$
10	37663	37258	36862	5.
11	37492	37008	36535	5.1
12	37306	36736	36184	5.2
13	37106	36447	35810	5.3
14	36893	36139	35414	5.4
15	36667	35814	35000	5.5
16	36428	35473	34567	5.6
17	36177	35117	34117	5.7
18	35914	34747	33653	5.8
19	35640	34365	33177	5.9
20	35357	33971	32688	6.
21	35064	33566	32190	6 1
22	34761	33152	31684	6.2
23	34450	32729	31171	6 3
24	34131	32298	30653	6.4
25	33805	31862	30130	6.5
26	33472	31420	29605	6.6
27	33133	30973	29079	6.7
28	32787	30523	28551	6.8
29	32438	30070	28025	6.9
30	32083	29615	27500	7.
31	31725	29159	26977	7.1
32	31363	28702	26458	7.2
33	30998	28246	25943	7.3
34	30631	27791	25433	7.4
35	30262	27337	24928	7.5
36	29891	26885	24428	7.6
37	29520	26436	23936	7.7
38	29147	25990	23450	7.8
39	28774	25547	22971	7.9
40	28402	25109	22500	8.

When $\left(w_1-R\frac{a}{l}\right)>o$, M increases with x; *i.e.*, M is a max. for $x=a$. (We must not consider $x\times a$, since V and hence M would be diminished). If $\left(w_1-R\frac{a}{l}\right)>o$, M increases as x decreases, which moves w_2 up to B at last. When the coefficient of x is zero, w_1 or w_2 may be supposed at B, or B must lie between them.

2/. *But* M *may be a max. when* w_2 *is to the left of* B. In this case regard $w_1+w_2=P$ as a a single force.

Call c_1=distance from the center of gravity of w_1 and w_2 to R, *i.e.*, from P to R,

and x=distance from A to P.

Then the above equations hold, on simply substituting P for w_1.

As before, when $\left(P-R\frac{a}{l}\right)>o$, M increases with x and is a max. when w_2 is over B, but it must not be supposed to the right of it, as the equation does not now include this supposition. This position of the load then gives M a *max.*

3/. If, however, $\left(P-R\frac{a}{l}\right)<o$, M increases as x decreases, whence the load is moved forward so that w_2 rests upon B.

Next, calling $w_1+w_2+w_3=P_1$, c_2= distance from P_1 the resultant of w_1,w_2,w_3 in position and magnitude to R, and x= distance from A to P; eq. (9) holds as before on substituting P_1 for w_1. We proceed as before to ascertain if M is a maximum when B is between w_3 and w_4 and so on for other positions of the loads.

65. As w_1, w_2 . . . pass off the span, they must no longer be included in the formulae for R, c, M, etc. For a framed truss, a is the distance from A to the apex that is taken as the center of moments for the opposite chord panel. As it is only necessary to consider half a truss, the maximum strains in the chords being the same for the other half when the load moves in an opposite direction, *we must not take* $a>\frac{1}{2}l$.

66. *Example.* Consider the three trusses, Figs. 5, 6 and 7, to be of 400 feet span, each with 20 panels, the panel lengths thus being 20 feet each. Let five equal weights w (as the locomotive excesses, art. 16, 38) be placed on the span at equal or unequal distances apart. Then $R=5w$ and in eq. (9), $\left(w_1-R\frac{a}{l}\right)=w\left(1-\frac{5a}{l}\right)$, which is positive when $a<\frac{l}{4}=80$ feet; hence art. 64, 1, to find the maximum chord strain on the first four panels from the abutment, the loads w, w . . . must extend from the center of moments for the panel considered (art. 65) towards the center. For the fifth chord panel $\left(1-\frac{5a}{l}\right)$ is negative, so that the second weight moves up, at least, as far as its center of moments; then proceeding as in art. 64, 2; $P=2w$, and $\left(P-R\frac{a}{l}\right)=w\left(2-\frac{5a}{l}\right)$ is +, so long as $a<\frac{2}{5}l=160$ feet. So that for panels 5, 6, 7, 8 (and 4 if preferred), the second

weight must be supposed up to the panel considered, to ascertain its maximum chord strain.

Finally, $\left(2-\frac{5a}{l}\right)<o$ for $a>160$, or 8 panel lengths. Therefore in art. 64, 3, put $P_1=3w \therefore \left(P_1-R\frac{a}{l}\right)=w\left(3-\frac{5a}{l}\right)$ is + when $a<\frac{3l}{5}=240$ feet.

Hence for panels 9, 10, (and 8 if desired) the middle weight is placed at their center of moments.

The above results are independent of the distances apart or magnitude of the equal weights. It is seen that the maximum moment for an end panel is when the front weight reaches to it; whilst the max. moment at the center is when the middle weight is at the center, and for intermediate panels the loads have intermediate positions. It will be instructive for the reader to test the above results, by assuming various positions of the loads for each panel in turn.

When the loads are unequal the application is equally simple and direct.

67. Referring to eq. (9), and regarding w_1 as the resultant of all the weights to the left of B, we see (as was remarked in art. 64) that *when* a has such a value that,

$$w_1-R\frac{a}{l}=o \therefore w_1 l-(w_1+w_2+\dots)a=o$$

$$\therefore \frac{w_1}{w_2+w_3+\dots}=\frac{a}{l-a},$$

that the greatest moment ever experienced at B obtains; and we see from the last eq. that this occurs when *the loads on either side of B are in the ratio of the segments into which it divides the span.* This conclusion is reached in DuBois, Graphical Statics, art. 73. Though this author seems to regard the analytical treatment of a given recurring system of moving loads as almost impracticable, (see his Preface, p. xi.)

It is believed that the above solution is practical and simple; in fact, much more so than the one by the graphical analysis.

COMPOUND SYSTEM.

68. As the span increases, the panel lengths become too long for economy, or the inclination of the web diagonals, for usual panel lengths, is not the best for economy, for the trusses previously figured. Hence the use of compound systems such as the whipple, fig. 9, the Trellis, the Post, or even bridges of "treble" &c. "intersections," where the ties cross three or more panels.

69. *Web Strains.*—In the truss fig. 9 of 200 feet span and 28 ft. high, divided into 12 panels, weights as before, let w, placed below the apices, denote the *panel dead load; p* placed above the apices, the *panel car load;* and E, the *locomotive excess*, being the two weights at d and h in the figures. It will be noticed that any weight as that at f can travel to either abutment only by one web system, as a B d D f H h J . . . . The weight at e must follow the other system, a B c C e . . . . The weights inked black thus travel towards either abutment only by the first system, the others by the second.

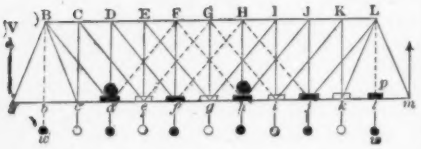
Now if the second engine is placed 50 back of the first, its position is g; but the interposition of a car $16\frac{2}{3}$ feet long, or different engine and tender lengths would locate it at h. As the object is to find the max. strain that can come upon each system in turn, we must place the second locomotive four panel lengths from the first, so that it will bear upon the same system as the first. This position may rarely happen, but it should be provided for in the sections of the web members, especially those near the center of the truss, such as the dotted "counters." The dotted lines $\overline{Bb}$ and $\overline{Ll}$ are "suspenders" like those in Fig. 7 and similarly strained to a max. of 46000 pounds.

70. The weight at l may be taken on either or both of the partial trusses into which we shall suppose Fig. 9 divided. As it only affects V, $\frac{1}{12}(w+p)=2555$ pounds in this instance, it may act with a different system from that taken, without altering the sections an appreciable amount.

With vertical end posts there is no uncertainty, for then the weight at l can only act with the *black* system, as a tie extends from l to top of end post, the tie from k being also carried there.

71. If we cut the truss through between $\overline{cC}$ and $\overline{dD}$ as in Art. 7, and apply forces at the cut parts equal and opposed

FIG. 9.



to the resistances, the total shearing force, S, is, of course, $V-2w$; but S is the *sum* of the vertical components on the two cut ties, and without knowing the amount carried by one tie we are unable to estimate it on the other. Hence this general method must first be applied to one partial truss and then the other independently. First take the partial truss $aBdDfFh$ . . . . , and call V the reaction at a due to the load on this truss. The reasoning of arts. 12 and 27 apply here in finding max. and min. S. Call Σw the *sum* of the *ws* between a and foremost locomotive on system taken; then having found V, when load, (engines in front) extends from farthest abutment we have

$S=V-\Sigma w$. Take moments about m,

Call l_1, the lever arm of E,

l_2, the lever arm of the resultant of the car loads p,

and m=the number of p's on the partial truss considered. Also let a panel length as $\overline{ab}$ be the unit of length. With the loads as in the figure $l_1=7$, $l_2=5$, $m=5$. We have as before, $w=14000$, $p=\frac{80000}{3}$ and $E=60000$.

$$V\,12=6\,w\,6+El_1+mpl_2$$

$$\therefore\ S=42000+5000.l_1+m.1390.l_2-\Sigma w.$$

In a similar manner we proceed for the other partial truss, finding the equation,

$$S=\tfrac{5}{2}\,w+\frac{E}{12}\,l_1+\frac{mp}{12}l_2-\Sigma w.$$

72. The results are entered in the following table. Note, from the figure, that as the live load moves two panels to the right, l_1 diminishes by 2, l_2 by 1, and m by 1. The table is thus very quickly formed. The max. shearing force on $\overline{aB}$ + 216108 lbs., found by supposing the whole bridge loaded as in art. 21. Thus

$$V=S=1\tfrac{1}{12}(w+p)+9\tfrac{1}{2}\times\frac{E}{12}=216108.$$

PARTIAL TRUSS $aBdDfF$ . . . .

Front Engine at	Piece.	$42000+5000.l_1+m.1390.l_2-\Sigma w=$	S.
d	Bd	$42000+5000.7+5.1390.5-0$	97750
f	dD, Df,	$42000+5000.5+4.1390.4-14000$	61240
h	fF, hF,	$42000+5000.3+3.1390.3-28000$	27510
j	hH, jH,	$42000+2500.3+2.1390.2-42000$	− 940
l	—	$42000+2500.\ +\ 1390\ -56000$	−24110
		PARTIAL TRUSS $aBcCeE$ . . . . $35000+5000.l_1+m.1390l_2-\Sigma w$	
c	cB	$35000+5000.8+5.1390.6-0$	116700
e	Cc, Ce	$35000+5000.6+4.1390.5-14000$	78800
g	eE, gE	$35000+5000.4+3.1390.4-28000$	43680
i	gG, iG	$35000+5000.2+2.1390.3-42000$	11340
k	—	$35000+2500.2+\ 1390.2\ -56000$	−13220

73. Be careful to note when one locomotive leaves the bridge and modify the formula correspondingly. S sec. i gives the strain on the ties as before, sec. $i=\frac{43.5}{28}=1.553$ except for Bc; its value for that tie being $\frac{32.6}{28}=1.165$. The values of S above are the actual strains on the vertical posts opposite them. If those posts were inclined as in the "trellis" bridge (in which the posts $\overline{Dd}$, $\overline{Ff}$, &c., take the positions, $\overline{Ed}$, $\overline{Gf}$, &c.; the corresponding ties $f\overline{D}$, $h\overline{F}$, &c., the positions $f\overline{E}$, $h\overline{G}$, &c.; braces reaching from

C to b and from $\overline{K}$ to l), we multiply S by sec. i to find the strains on them as well as the ties that are equally inclined. In the trellis, as in the triangular, some web members near the center take obverse and reverse strains.

74. It is implied in the previous computations that the reactions at the abutments of each partial truss are to be determined by the simple law of the lever *independently* of the other partial truss.

Unless the counter rods have little or no strain on them for a uniform load this assumption may be incorrect.

To prove it: take the extreme case, that the main ties $\overline{Bc}$, $\overline{Ce}$, $\overline{Eg}$, are too long to be in action, and that counters, from c to E, $\overline{eG}$, $\overline{gI}$ are *taut* (malicious or ignorant persons might screw up the counters so as to relieve the main ties above from strain), then the loads c, e and g must inevitably go to m. Now conceive panel cD severed. The total shear on this panel (art. 71) is,

$$V-2w=\frac{11w}{2}+\frac{7E}{12}+\frac{9p}{12}5-2w=146500=S.$$

But since the shear w on the supposed rod $\overline{c\,E}$ acts up, the actual shear on tie $\overline{b\,D}$ is $S+w=160500$ lbs.; *whereas we shall proportion it for* 97750 *lbs. shear as previously found?* Similarly for other panels. Practically, the counters are loose when the truss is first set up; the main ties are then necessarily in action; for even if a little long ($\frac{1}{64}$ inch say), the roadway sinks the apex and thus brings them into action (as the upper chord apex sinks too, the chord at this apex is thus unequally strained). Now, if the counters are tightened, *part* of the weight at c, e, . . . *will go* to m, from the law of decomposition of forces; and *the greater the initial strain on the counters, the larger the weight on the partial truss,* aBcCeE . . . *that is transferred to the right abutment.* The counters being of much lighter section than the main ties will stretch more and thus counteract this tendency, especially on the partial truss on which the locomotives bear.

95. As stated then, the partial trusses cannot act independently except when the counters are not strained for a uniform load. If they have a slight initial strain on them, the strains may be increased on the web members somewhat—an additional reason for supposing the second locomotive to bear upon the same system as the first, as we have done. It is then not only useless, but may be prejudicial to put counter rods, screwed taut, in panels where there is never any reversion of strain, as from c to E etc. With the loads assumed, S is—, (art. 73) for counters d F and j H, but a slightly greater load would bring them into action, hence they should be retained and their section assumed, say at 2 sq. in.

76. The preceding reasoning applies to all compound systems. In finding S for the simple systems, as figs. 5, 6, 7, no assumption was made as to the abutment to which any particular weight was transferred. But S is the total shear, and for figs. 5 and 6, if the counter carries any strain (as explained in art. 74) the shear on the main tie or brace is increased by that strain.

In the triangular truss, fig. 7, there is no uncertainty as to the strains; as the same piece, where necessary, takes tension and compression both.

77. It is recommended as good practice, where separate counter rods are used, "to put a *light* load on the bridge and then strap the counters down taut. They should not remain taut under full symmetrical loads, but should be tight enough to keep quiet under unsymmetrical loads; a medium that can be struck." "Practically the counter ties remain tight if adjusted intelligently and are not tampered with." Similar remarks apply to "keeping wooden counterbraces" recommended by Haupt. As any deflection of a truss is accompanied by an increased length of main ties, and a shortening of the counter diagonals, if the counters are strapped down when there is a light load on the bridge, for a full symmetrical load they will be loose; for a dead load only, they will be tight. This is as it should be.

(*Remark.* The whole of the rearmost loc. excess was supposed to bear at one apex only, thus giving slightly larger strains than the true ones, to *allow* somewhat for improperly adjusted counters.)

78. *Chord Strains.*—Suppose the truss loaded at each lower apex with $(w+p)=w'$ (the weights below the fig. can now be taken for w') and of the two weights

30,000 lbs. each, either 3 panels (50 ft.) apart, or a greater distance, if the chord strains are thereby increased.

As before, we assume that each partial truss acts independently of the other; find the strains on any chord piece as $\overline{CD}$, due to each partial truss and add them for the total strain on that member. If it is simpler, the reader may draw the two partial trusses separately to estimate the effect of each.

79. *The Locomotive Excess*, E=60,000 lbs., is made up of the two weights, 30,000 lbs. each. For convenience call the foremost P, the rearmost, P′.

Now the chords may receive their maximum strains when P and P′ act in the same system, 4 panels apart; or in different systems, 3 panels apart. The principles of art. 34 are of some assistance, but we can only determine by actual trial, for each chord panel in turn, the proper relative position of P and P′ that give the max. strains for that panel. Hence I have estimated the effect of P and P′ separately, and have taken those positions of P and P′, *either* 3 *or* 4 *panels apart*, that gave the greatest strains for each chord panel. The height of truss was taken as before at 28 ft. The results are as follow:

Piece.	P at	P′ at	Max. Strains.	P, 4 panels from P′.
			lbs.	lbs.
ac	*b*	*e*	28274	—
cd	*c*	*g*	47619	47619
de or BC	*d*	*h*	62500	62500
ef or CD	*d*	*g*	75893	71433
fg or DE	*e*	*h*	84821	74410
EF	*f*	*i*	87798	71433
FG	*f*	*i*	87798	71433

Thus for $\overline{cd}$, $\overline{de}$ and $\overline{BC}$, the weights are 4 panels apart, for the others 3. Note again, that for some panels P is adjacent, and for others a panel distance from, the panel considered. It will be noticed above that for panels near the centre the strains are considerably greater when P and P′ are 3 panels apart, than when they are 4 panels apart.

80. To illustrate the method of computation, call *a panel length*=ab=1; the height of the truss is then $28 \div \frac{5.0}{3} = \frac{84}{50}$. With P at c, its reaction at a is $\frac{10}{12}$ P. If $\overline{de}$ is cut, rotation about C would occur. The moment about C is $\frac{10}{12}$ P. 2 =50000. Next suppose P at d, the reaction is $\frac{3}{4}$ P. If $\overline{de}$ is cut, D is the point of rotation, and the moment is thus $\frac{3}{4}$ P 3=67500.

Now when P is at c, conceive P′ at f; its reaction is $\frac{7}{12}$ P; and with D as a center of moments for $\overline{de}$ cut the moment= $\frac{7}{12}$ P 3=52500. (It is needless to consider P′ at g, in this case, as V is less, also the point of rotation, for $\overline{de}$ cut, being C, for the truss g E e l' . . ., the lever arm is less too).

Next with P at d, let P′ be at g ∴ V= $\frac{1}{2}$ P. Then for $\overline{de}$ cut, the moment about C is $\frac{1}{2}$ P. 2=30000.

Lastly with P at d, conceive P′ at h ∴ V=$\frac{5}{12}$ P. For $\overline{de}$ cut, D is the point of rotation for truss h F f D . . . ., hence the moment is $\frac{5}{12}$ P. 3=37500.

Collect now the moments for the piece $\overline{de}$.

Piece.	P at	Moment	P′ at	Moment	Total.
de	*c*	50000	*f*	52500	102500
de	*d*	67500	*g*	30000	97500
de	*d*	67500	*h*	37500	105000

With P at d and P′ at h, the actual moment is greatest. Divide it (105000) by the height of truss $\frac{84}{50}$ and we get the strain in $\overline{de}$=62500 lbs.

81. We see how much simpler the treatment of the simple systems is than the compound; still, if we desire to know the "true inwardness" of the compound systems, extra work is unavoidable.

It may be urged that when P′ passes to the right of all the counters none of its weight can be transferred to a: true, but with the uniform load in addition on the bridge, the law of the lever holds for each partial truss, since counters are designed in those panels where loads have to be transferred to the farthest abutment and the *effect must be the same in the final summation whether the two engines and the uniform load are treated separately or conjointly.*

82. For the uniform load, w'=w+p= 14000+16666=30666 per panel; as before we *assume* that the partial trusses act independently and afterwards combine their effects for the same chord panel.

Thus to find the strain on $\overline{BC}$ due to the black weights: $V=\frac{1}{2}6\ w'$, with d as a center of moments,

$$(\text{Strain on } \overline{BC})\times \overline{dD}=V\times\overline{ad}-w'\times\overline{bd}$$

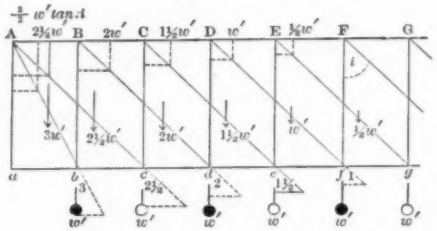
Similarly for the other partial truss, conceive $\overline{bc}$, $\overline{Bc}$ and $\overline{BC}$ cut and take the intersection of the first two, c, as a center of moments (art. 36). The reaction at a is $V'=\frac{5}{2}w'$

$$\therefore\ (\text{Str. on } \overline{BC})\times\overline{Cc}=V'\times\overline{ac}$$

The sum of the strains on $\overline{BC}$ thus found, added to that found for the locomotive excess, gives the total strain on $\overline{BC}$ which is evidently the same as that on $\overline{de}$.

83. The following is a more convenient method. The reaction at a due to the black weights is $3w'$; hence (art. 7), the *shears* on $\overline{bA}$, $\overline{dB}$, $\overline{f}$D are $3w'$, $2w'$, w', respectively as is marked, on the half truss with vertical end-posts, Fig. 10. The shearing forces on the ties of the other partial truss are as marked on

FIG. 10.



them $2\frac{1}{2}w'$, $1\frac{1}{2}w'$, $\frac{1}{2}w'$. In fact $\frac{1}{2}$ of the w' at g (Fig. 9) goes to either abutment (if the counters do not act). At E the pull on the tie gE is decomposed into $\frac{1}{2}w'$ acting down the post Ee and $\frac{1}{2}w'$ tan. i, compressing EF, ($i=g$Ee).

At e, the $\frac{1}{2}w'+w'(ate)$ acting vertically, is decomposed in the directions $\overline{Ce}$ and $\overline{ef}$, thus giving the strain on $ef=1\frac{1}{2}w$ tan. i. The shearing force on $\overline{Ce}$ is thus $1\frac{1}{2}w'$. Hence the pull on $\overline{Ce}$ at C gives $1\frac{1}{2}w'$tan. i, strain on CD, and $1\frac{1}{2}w'$ strain on post $\overline{Cc}$; and so on for all the weights, except that the pull on Ab, causes a strain on AB of $3\ w'$ tan. aAb $=\frac{3}{2}w'$ tan. i. Put aA$b=i_1$. The total strain on AB$=(\frac{3}{2}+2\frac{1}{2})w'$ tan. $i=3w'$tan. $i_1+2\frac{1}{2}w'$ tan. i.

Strain on BC$=$strain on AB$+2w'$ tan. i.
Strain on CD$=$strain on BC$+1\frac{1}{2}w'$ tan. i.
&c., &c.

Similarly,

strain in $\overline{bc}=3w'$ tan. $i_1=\frac{3}{2}w'$ tan. i.
strain in $\overline{cd}=$strain in $\overline{bc}+2\frac{1}{2}w'$tan.$i$, &c.

Hence the rule.

Multiply the shear on each inclined web piece by the tangent of its inclination to the vertical. The summation of these products from the abutment to any chord piece gives its total strains.

If the chord strain at center agrees with that found by moments the whole work is correct. This method can be applied to any truss.

83. Now by the principle of moments, the expressions for the strains in $\overline{BC}$, $\overline{CD}$ . . . , cd . . . are the same for Figs. 9 and 10. In fact the same method may be applied to Fig. 9, regarding the inclination, &c., at the ends, and the above rule deduced. The strains for the truss Fig. 9 are entered in the following table. By computation, we find, tan. $i=1.19$; tan. $i_1=.595$.

84. The total strain on $\overline{ac}$ Fig. 9 is the same as for Fig. 7, 128669 lbs. Since the shear on aB is $1\frac{1}{2}\ w'$ we find the strain on ac due to uniform load $1\frac{1}{2}w'$ tan. $i_1=100354$.

From table, art. 79, the max. strain due to E is 28274 which gives 128628 lbs. strain on $\overline{ac}$. The difference, 41 lbs., between this result and the former is due to carrying *tan.* i to two decimal places only.

Piece.		Increments.	Strains.
bc	$5\frac{1}{2}w'$ tan. i_1	100354	100354
cd	$2\frac{1}{2}w'$ tan. i_1	45616	145970
de or BC	$2\ w'$ tan. i	72984	218954
ef or CD	$1\frac{1}{2}w'$ tan. i	54738	273692
fg or DE	w' tan. i	36492	310184
EF or FG	$\frac{1}{2}w'$ tan. i	18246	328430

Taking moments about g we have

Strain in $\overline{FG} = (1\frac{1}{2}\,w.100 - 5w.50) \div 28$
$= 328550$ lbs.

The slight difference between this result and that given in the table, shows the correctness of the work. The "increment" column can be "run up" from the bottom, adding $\frac{w'}{2}$ tan. i each time until we reach $\overline{cd}$.

85. Combining these results with those in art. 79 we enter them, also the web strains in the following table:

Piece.	d.	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″				□″	′			lbs.	
U. Chord, BC	$13\frac{1}{8}$	15	$\frac{3}{4}$	281454	.39	9050	31.1	$10\frac{0}{8}$	4	$10\frac{0}{8}$	6911	
CD	"	"	1	349585	"	9270	37.7	"	"	"	8378	
DE	"	"	$1\frac{1}{8}$	395005	"	"	42.6	"	"	"	9467	
EF	"	"	$1\frac{1}{4}$	416228	"	"	44.9	"	"	"	9978	
FG	"	"	$1\frac{1}{4}$	416228	"	"	44.9	"	"	"	9978	44712
Posts, aB	$13\frac{1}{16}$	30	$\frac{31}{16}$	251766	.36	5340	47.15	32.6	"	"	20495	
Cc	10	34	$\frac{3}{8}$	78800	.17	4400	17.9	28	"	"	6683	
Dd	"	"	$\frac{1}{4}$	61240	0	3750	16.3	"	"	"	6085	
Ee	"	"	$\frac{1}{8}$	43680	0	"	11.62	"	"	"	4338	
Ff	$8\frac{3}{8}$	40	$\frac{3}{8}$	27510	0	3140	8.76	"	"	"	3270	
Gg	"	"	"	11340	0	—	8.76	"	2	"	1635	42506
Lower Chord				1476889	.39	10420	141.73	$10\frac{0}{8}$	4	"	31496	31496
Suspender Bb				46000	0	7500	6.13	28	"	"	2288	
Ties, Bc				135955	.3	9750	13.94	32.6	"	"	6064	
Bd				151806	.25	9370	16.2	43.5	"	"	9396	
Ce				122376	.17	8780	14	"	"	"	8120	
Df				95106	0	7500	12.7	"	"	"	7366	
Eg				67835	0	7500	9.04	"	"	"	5243	
Fh				42723	0	7500	5.7	"	"	"	3306	
Gi				17611	0	7500	2.35	"	"	"	1363	
Hj							2.	"	"	"	1160	44306

86. The value of θ for the chords is the same as in the previous truss examined, also for $\overline{aB}$ and $\overline{bB}$. From the table of shearing forces (art. 72), we find the following values for θ, according to the principles of arts. 26, 27:

Piece.	Maximum S.	Minimum S.	θ.
aB	216108	77000	.36
cB	116700	35000	.3
dB	97750	24110	.25
Cc, Ce	78800	13220	.17
Dd, Df	61240	940	0
Ee, Eg	73680	11340	0

The black weights were regarded as acting on the same partial truss. Min. S on $\overline{cB}$ is then due to dead load only, and is 35000 lbs. $= 2\frac{1}{2}w$. Min. S on dB is the same as for $\overline{Lj}$ when front engine is at l (art. 72). Similarly min. S on $\overline{Cc}$, $\overline{Ce}$ is the same as for $\overline{kK}$, $\overline{Ki}$ when "front engine is at k." The dotted counters and hence the posts $\overline{Ff}$ $\overline{Gg}$ sustain no strain from a uniform load. Hence for them $\theta = o$. It will be noticed that for the same panel θ, and hence b is less for the "compound" than for the "simple" systems. In the foregoing table the *posts* were regarded, as "hinged at one end."

87. The following is the

BILL OF MATERIALS.

Whipple Truss—200′ span—28′ high.

	lbs.
Posts	42506
Upper chord	44712
20 p. c. for castings, &c	17444
Ties, counters and suspenders	44306
Lower chord	31496
15 p. c. on two last, for bolts, &c.	11370
Floor beam loops	5000
Lateral bracing	11400
Floor beams (iron)	24500
Iron stringers	60060
Rails, cross ties, &c	33200
Total weight of bridge	325934
Assumed weight	336000
Assumed weight too great by	10066

The weight of this whipple truss (325934) is thus 3915 lbs. less than the weight of the Triangular Truss (329849) allowing $\frac{1}{8}''$ as the least thickness of metal. If, however, as seems more proper, the vertical posts of the triangular truss that only sustain 2500 lbs. *dead* load, be given a thickness of $\frac{1}{4}$ inch, their section will be 4.5 square inch; and the weight of the triangular truss is reduced 4200 lbs. making it the lightest of the two. The weight of flooring, rails, loops, lateral bracing, etc., was assumed the same in both trusses. See art. 108 for a further comparison.

88. The Quadrangular Truss however, is more built than any other in this country, on account of its economy in first cost, the *square joints* being more easily and accurately machined than others; the posts too are vertical, thus ensuring less flexure under their own weight than inclined posts, and with certain details they can be made "flat at both ends," bearing against the upper chord and the upper flange of the floor beam.

It is evident from what precedes that "compound systems" require greater accuracy in filling than simple systems; and where counter rods are used, they should be properly tightened and often inspected, or grave consequences may ensue. It is evident, likewise, that the greater the number of systems used, the more care is required to make the actual strains agree with the computed; in other words, to cause each partial system to act independently of every other. The investigation of the maximum chord strains is more troublesome the greater the number of partial systems used. Many of the largest spans built or being built in this country, varying from 300 to 525 feet in length, are "double intersection," although treble and quadruple intersections are by no means unknown.

In latticed bridges where the diagonals are connected at their intersections. the strains are perfectly indeterminate, It would certainly then seem advisable to use those patterns of web in which the strains go where they are computed to go.

The weights computed above are, so far as I know, above average. Are they too great for a first-class road? The effects of high speed, with snow, great cold and side wind (for which no provision is made in the chords), ill fittings and perhaps some counters unadjusted should be considered conjointly with the statical loads in answering this question.

89. Let us now suppose the live load uniformerly distributed, and ascertain what percentages are necessary to add to the chord strains induced to equal the *maximum* chord strains (see art. 52).

The uniform live and dead load per panel is now $(168000+200000+60000) \div 12=35666$ lbs. which causes the following strains in the chords (see art. 84 for method of ascertaining strains):

BC=254654,	EF=381980
CD=318317,	FG=381980
DE=360759,	

whence comparing with the maximum strains given in the table, we find that for BC and CD, we must add 10 p. c., for DE, 9½ and for EF and FG, 9 p. c. to strains just found to get the corresponding maximum strains. The percentages are greater, except for end panels, than for the simple systems (see art. 52); hence a comparison of weights based on the same percentage, is favorable to the compound system, as drawn in Fig. 9, at least.

90. It is worthy of note that *the strains in the chords are greatest where the shearing force is zero.*

This is evident from the reasoning in art. 83: for as the increment of strain is, *the shear on the tie* $\times$ *tan i; where* the shear on the tie is zero, the chord strain is a maximum. Thus, in Fig. 10, since $s=o$ on tie F*h*, there is no increment of strain to add to the strain on EF, at F. At E, $\frac{1}{2}$ *w tan i* is added to the strain on $\overline{DE}$ etc. We see then, that $\overline{EG}$ is more strained than any other part of the upper chord.

Similarly for irregular loading.

The above result is true, irrespective of the number of panels, hence for an indefinitely great number, as we may suppose a *solid beam* made up of.

This result must not be confounded with that of art. 64, where the object was to find that position of the load for which a particular chord piece would be strained most.

91. Let us now estimate the whipple as a *deck* bridge with leaning end ties,

trusses 14′ apart from centre to centre. Thus in Fig. 9 extend the upper chord to the abutments at A and M, discard Bc aB and ab; draw the ties bA, cA and the post Bb (similarly at the other abutment) and conceive the load on the upper chord. The chord strains are the same as for the through bridge, Fig. 10; the maximum shear on the ties is the same as before, but the maximum strain on a post now is when the front engine is directly over that post, or two panels nearer the abutment than before, thus increasing the strains on the post over those formerly obtained. On this account θ is not the same for the posts as before. The results are entered in the following abridged table of weights, from which the Bill of Materials is made out as before. To avoid mistake in determining "*min. B*," the partial trusses may be drawn separately, when the principles of art. 27 apply directly:

Piece.	d	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″								lbs.	
U. Chord, $\overline{AB}$	13½	15		193589	.39	9050	20.1	100/3	4	10/3	4467	
BG	"	"		1858500	"	9270	200.5	"	"	"	44556	49023
Posts, Bb	12	28	1	137000	.3	5840	23 5	28	"	"	8773	
Cc	"	"	9/16	116700	.3	5840	20.	"	"	"	7466	
Dd	"	"	¼	97750	.25	5610	17.4	"	"	"	6496	
Ee	10	34	5/16	78800	.17	4400	17.9	"	"	"	6683	
Ff	"	"	⅛	61240	0	3750	16.3	"	"	"	6085	
Gg	"	"	3/16	46000	0	3750	12.3	"	2	"	2296	37799
Lower Chord				1346987	.39	10420	129.2	100/3	4	"	28711	28711
Ties, Ab				159605	.3	9750	16.4	32.6	"	"	7128	
Ac				181235	.3	9750	18.6	43.5	"	"	10788	
Other ties (as before)								43 5	"	"	35954	53870

Bill of Materials.

Whipple Truss (Deck)—200′ span—28′ deep.

	lbs.
Upper chord and posts	86822
20 p. c. for castings, &c.	17364
Ties and lower chord.	82581
15 p. c. for bolts, &c.	12387
Lateral tie rods and struts.	11400
13 floor beams, 24″ deep.	22630
Iron stringers, 26″ deep.	60000
Rails, cross ties, &c.	33200
Total weight.	326384
Assumed weight.	336000
	9616

Minimum Material.

92. The most economical inclination of the web ties, irrespective of the rest of the bridge, is easily found to be 45°. Thus call x the height of truss, d the horizontal distance between the extremities of the tie, i its inclination to the vertical, and s the shearing force on it. The strain on the tie is thus s sec. i; the cross section s sec. $i \div b$, and as its length is $\sqrt{d^2+x^2}$ its volume, is since sec. $i = \frac{\sqrt{d^2+x^2}}{x}$,

$$V = \frac{S}{b}\frac{d^2+x^2}{x}$$

which is a minimum for $x=d$, or when $i=45°$: *i. e., the material in the web ties is a minimum when they are inclined* 45° *to the vertical.*

93. The same would be true for the web struts, if b was assumed constant for them, but b = the strain per square inch allowed, diminishes with the length of the strut, and the above simple relation does not hold. The general law of maxima and minima is this: that any function of a single variable is a maximum or a minimum for those values of the variable derived by placing the first differential coefficient of the function equal to zero. Thus, $v=$ a maximum or a minimum in the eq. above when

$$\frac{dv}{dx} = \frac{2x^2-d^2-x^2}{x} = o \quad \therefore x=d$$

It is evident that $x=d$ gives a min.

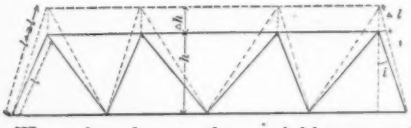
It is proved by noting that $\frac{d^2v}{dx^2}=\frac{2d^3}{x^3}$ is positive; for as the second differential is $[\pm]$ the function is $\left\{\begin{matrix}\text{a min.}\\ \text{a max.}\end{matrix}\right\}$ for that value of the variable.

94. Having given for a truss with parallel chords, the *span*, *loads*, *panel lengths*, *pattern*, *details*, and *formulæ for* "b"—the unit strains required the most economical height of truss? Denote the weight of the material that varies with the height of the truss (since it is a function of h), by F (h). This material is such as given in preceding tables, as computed from the strains on web and chords. The castings, both etc., transverse bracing, flooring system, pins and loops, do not vary perceptibly with h, hence F (h)= weight of material computed *on* chord and web strains only; which is easily selected from the table of weights. Now, if F (h) is a minimum we must have

$$\frac{d\mathrm{F}h}{dh}=\lim\frac{\mathrm{F}(h+\triangle h)-\mathrm{F}h}{\triangle h}=o \quad . \quad . \quad (10)$$

95. Denote the weight of upper and lower chords, that varies with h, by

Fig. 11.



W_c; also denote the variable part of the weight of a web member by w, its inclination to the vertical by i and its length by l.

Now change the height of the truss (see Fig. 11) to $h+\triangle h$ and call the new value of l, $l+\triangle l$.

96. As by assumption, the panel lengths remain the same as well as the diameter of the upper chord, the strains in, and hence the weight of, the chords are now $\frac{h}{h+\triangle}$ of the first, h and $h+\triangle h$ being respectively the former and present lever arms of the chord strains.

∴ *New weight of variable material in chords,*

$$W'_c=W_c\frac{h}{h+\triangle h}=W_c-W_c\frac{\triangle h}{h+\triangle h} \quad . \quad . \quad . \quad . \quad (11)$$

97. If S denote the shear on the web member, whose weight (the part that varies with h) was w, inclination to vertical i and length l, the former strain on it was sec. $i=S\frac{l}{h}$ and hence its volume was $\frac{S\frac{l}{h}}{b}l=\frac{sl^2}{bh}$.

The new volume is similarly,

$$\frac{S(l+\triangle l)^2}{b'(h+\triangle h)}$$

in which, for struts (see art. 53)

$$b=\frac{38500(1+\theta)}{\left(4+\frac{1}{10}\frac{l}{d}\right)\left(1+c\frac{l^2}{r^2}\right)}$$

and b' equals the same expression on changing l to $(l+\triangle l)$. For ties $b=b'=7500(1+\theta)$.

Hence *the new weight of the variable material in the web member*=$w\times$ ratio of new to old volumes

$$=w\frac{(l+\triangle l)^2}{l^2}\cdot\frac{h}{h+\triangle h}\cdot\frac{b}{b'} \quad . \quad (12)$$

Actually dividing b by b'; for struts, we get

$$\frac{b}{b'}=1+\frac{\frac{\triangle l}{10d}\left(1+\frac{c l^2}{r^2}\right)+\left(4+\frac{1}{10}\frac{l+\triangle l}{d}\right)(2l+\triangle l)\frac{c\triangle l}{r^2}}{\left(4+\frac{1}{10}\frac{l}{d}\right)\left(1+c\frac{l^2}{r^2}\right)}$$

$$=1+k\triangle l.$$

For ties this ratio is 1. Hence to avoid complication, simply notice that for ties the fractional term k, in the value of $\frac{b}{b'}$ for struts is zero, and as a consequence, when a tie is considered, the term m given below is zero. Now substitute the above value of $\frac{b}{b'}$ in (12) and reduce.

The first term of the 2nd member must now be written,

$$w\frac{(l+\triangle l)^2}{l^2}\frac{h}{h+\triangle h}=w+w\frac{2hl\triangle l+h\triangle l^2-l^2\triangle h}{l^2h+l^2\triangle h}$$

So that the new weight of the web member is

$$\left(w+w\frac{2hl\triangle l+h\triangle l^2-l^2\triangle h}{l^2h+l^2\triangle h}+w\frac{(l+\triangle l)^2}{l^2}\cdot\frac{hk\triangle l}{h+\triangle h}\right)=w'$$

and the sum of these, for the whole web we indicate by $\Sigma w'=\Sigma w+\Sigma$, &c.

98. Now, $F(h)=W_c+\Sigma w$

$$F(h+\triangle h)=W'_c+\Sigma w'$$

$$\therefore\ \frac{F(h+\triangle h)-F(h)}{\triangle h}=-\frac{W_c}{h+\triangle h}+\frac{\Sigma w'-\Sigma w}{\triangle h}$$

Now by the principles of limits; *lim.* $\frac{\triangle l}{\triangle h}=\cos.\ i$, as $\triangle h$ and therefore $\triangle l$ diminish indefinitely.

Hence for a minimum weight of bridge,

$$\frac{dFh}{dh}=\frac{-W_c}{h}+\Sigma\left(\frac{2h\cos.\ i-l}{lh}+\cos.\ i\times lim.\ k\right)=o$$

The *lim.* k we find by making $\triangle l=o$ in the value of k. Now since $\cos.\ i=\frac{h}{l}$, the above becomes on multiplying through by h

$$W_c=\Sigma\left(\frac{2h^2}{l^2}-1+\frac{h^2}{l^2}(lim.\ k)\ l\right)w$$

Now, $\frac{2h^2}{l^2}-1=2\cos.^2 i-1=\cos.\ 2\ 1$

And

$$(lim.\ k)\ l=\frac{\frac{l}{10d}\left(1+e\frac{l^2}{r^2}\right)+\left(4+\frac{1}{10}\frac{l}{d}\right)\frac{2el^2}{r^2}}{\left(4+\frac{1}{10}\frac{l}{d}\right)\left(1+e\frac{l^2}{r^2}\right)}$$

Or putting $(lim.k)\ l=m$, and reducing:

$$m=\left\{\frac{\frac{l}{d}}{40+\frac{l}{d}}+2\,\frac{e\frac{l^2}{r^2}}{1+e\frac{l^2}{r^2}}\right\}\quad\ldots\ (13)$$

whence we find the following simple relation:

$$W_c=\Sigma w\left(\cos.\ 2\ i+\frac{h^2}{l^2}m\right)\ldots.\ (14)$$

∴ When the truss has the most economical height, the variable weight of the two chords must equal the sum of all the terms found by multiplying the variable weight of each web member by the cosine of twice its inclination to the vertical plus a term varying with the ratios of h to l and of l to d; noting that for ties, or posts where b is taken constant, this last term $\left(\frac{h^2}{l^2}m\right)$ *becomes zero.*

For vertical members, $i=o$, cos. 2 $i=1$ and $h=l$.

99. For $i<45°$, cos. 2 i is +; $i=45°$, cos. 2 $i=o$; $i>45°$, cos. 2 i is −.

The above result is true for any pattern of truss whatever with parallel chords *in which* the strain on the chords varies inversely as the heights and the shear on any web member is not altered by a change of height.

The result then, it seems, applies to all usual forms of trusses with parallel chords.

100. Let us draw a few general conclusions from our formula :

1/. The depth of deck bridges with vertical end posts should be less than that of through bridges of *same design*, since the posts are heavier and thus W_c must be greater to satisfy eq. 14, which requires a lower truss. With no end posts for the deck bridge, if the web is thereby lighter the reverse may be the case.

2/. The greater the number of panels, the heavier the web, for the same height, which requires a lower truss to bring about the equality of eq. 14 (supposing W_c for the same height to be the same for any number of panels, which depend upon the relative unit strains of upper and lower chords).

3/. Continuous girders should have a less depth than simple girders, since for same weight of web, it is known that M_c is less than for a simple girder.

4/. Trusses with two or more web systems should be built deeper than similar designs with one web system, since *cos.* 2 i is nearer o in the first case, hence W_c should be less and the truss higher.

101. If we suppose b (=strain per square inch) *constant* for braces as well as ties $m=o$ and eq. 14 becomes

$$W_c=\Sigma w\ cos.\ 2\ i\ \ldots\ldots\ (15)$$

In Van Nostrand's Magazine for Jan. 1877, p. 42, is an article by Emil Adler, C.E., on the most economical depth of girders, in which he deduces the equivalent of eq. 15. The general method fol-

lowed above is founded upon that of Mr. Adler; but it will be found that the supposition that b is constant will not give correct results in practice, hence I gave b the variable value, art. 97, and find the results to agree closely with practice. This should be so, since the value of b assumed agrees closely with values now used in America.

102. If all the web members are inclined 45°, as in the Warren girder *cos.* $2i=o$ $\therefore$ $W_c = o$ or the height of the truss is ∞. Hence 45° is not the most economical angle—on the supposition that b is constant—for this truss. It is hardly probable that eq. 14 would change this conclusion, which is different from that often given in text books.

103. *Applications.*—In the Triangular Through Truss, Fig. 7, it was assumed that the unit strains are constant for all members but the three braces in the half truss, hence $m=o$ except for braces 1, 3, 5.

From the table art. 42 we find

Weights of chords $= W_c = 74{,}947$
" vertical members $= W_v = 14{,}336$
" ties and counters $= W_t = 29{,}580$
" 3 braces $= W_b = 46{,}879$

Now, $i=30°46'$ $\therefore$ *cos.*$2i=.477$; and for 3 braces, $\frac{l}{d}=30$; also in eq. 13 for "hinged ends," &c., $c_{-2}=\frac{4}{9000}\left(\frac{l}{d}\right)^2$ and, $\frac{h^2}{l^2}=.738$. Hence for the 3 braces, $m=\frac{3}{7}+\frac{4}{7}=1$;

$$\Sigma w(\text{cos. } 2'2+\frac{h^2}{l^2}m)=46879(.477+.738)=56{,}958$$

Also

W_t cos. $22'=31280\times.477=14920$

For the vertical members cos. $22'=i1$

Now summing the results, we should have according to the rule of art. 98,

$$W_c=W_v+W_t \text{ cos.}2i+W_b\left(\text{cos.}2i\frac{h^2}{l^2}m\right)$$

But the numerical values give,

$W_c = 74947<14336+14110+56958=85404.$

104. With a less height W_c would be larger. Let us then try $h=27$ ft.

It is far more direct now to compute the new weights of chords and web from eqs. (11) and (12).

Thus in eq. (11) making $\triangle h=-1$, we find the new weight of the chords to be,

$$W'_c = 74947\ \tfrac{28}{27}=77723.$$

Similarly, the new weight of vertical members is,

$$W'_v = 14336\ \tfrac{27}{28}=13824.$$

From eq. (12) making $\frac{b}{b'}=1$, we get the new weight of ties and counters,

$$W'_t = 29580\left(\frac{31.7}{32.6}\right)^2\cdot\tfrac{28}{27}=29000.$$

And from the same eq. (12) we find the new weight of braces 1, 3 and 5 to be

$$W'_b = 46880\left(\frac{31.7}{32.6}\right)^2\cdot\frac{28}{27}\cdot\frac{b}{b'} = 44455.$$

The braces were assumed, as before, of $13\frac{1}{16}$" diameter. The new length of a brace is 31'.7; hence

$$\left(\frac{l}{d}\right)=29 \text{ and } \frac{b}{b'}=\frac{393}{406}.$$

We find, *cos.* $2i=.448$.

Apply eq. (14) again to the new weights:

$$W'_c = 77723\ (13824+29000\times.448 +44455(.448+.706)=78117$$

The truss may be one or two-tenths of a foot lower there for economy. The amount saved though is not worth the computing, for in the change from a height of 28' to one of 27' the amount saved is only 740 lbs. as we find from the above.

The time may more profitably be spent in ascertaining the best diameters of compression members for economy, regard being had to the castings and pins at the same time.

105. For the whipple through truss, Fig. 9, we get from the table, art. 85

$$W_c = 76208$$

Tie $\overline{Bc}\times$cos. $2i=6064\times.477=2892$

(Other ties and counters)$\times$cos. $2i'$ $=36000\times-.174=-6264$

$\therefore$ Σw_t cos. $2i=-3372$

Regard b as constant for posts $\overline{Ff}$, $\overline{Gg}$,

$\because$ $W_v=\overline{Bb}+\overline{Ff}+\overline{Gg}=7193$

Also $W_p=\overline{Cc}+\overline{Dd}+\overline{Ee}=17106$

For these posts $\frac{l}{d}=34$, and for a "one pin end," $c\frac{l^2}{r^2}=\frac{1}{3000}\frac{l^2}{d^2}$ and $W_p(\cos. 2i+m)=17106\ (1+\frac{3}{14}+\frac{1}{18})=34469$

For the brace Ba, we have as before,

$$W_b\left(\cos. 2i+\left(\frac{h}{l}\right)^2 m\right)=20495(.477+.738)=24901$$

Now from art. 98 we should have for economy

$$W_c=\Sigma w_t \cos. 2i+W_v+W_p(1+m')+W_b\left(\cos. 2i+\left(\frac{h}{l}\right)^2 m\right)$$

whereas we find,

$$W_c=76208>-3372+7193+34469+24901=63191$$

W_c is too great, hence the height should be greater. A height of 29 feet may now be tried.

The influence of the diagonals is very small in our equation, since *tan* $dB\bar{b}=50°$ or nearly 45° (art. 92). In a similar manner it is found that the height of the Whipple Deck Truss should be increased to 29 feet.

106. The Pratt Truss, through bridge, was next computed, for same span, loads, No. panels and height (28′) as before. The strains have already been given. The end brace was inclined, as in Fig. 9. Using the lettering of that Fig. the posts $\overline{Cc}$, $\overline{Dd}$ were given a diameter of 12″; the other of 8″ to 10″, the end brace and chord as before.

On making out a "Bill of Materials," the total weight of bridge was found to be 333,800 pounds.

From the table of weights,

$W_c=75{,}095$ pounds.

Ties and counters $=W_t=36914$, also *cos.* $2i=.477$

$W_v=\overline{B\bar{b}}+\overline{Ee}+\overline{Ff}+\overline{Gg}=18654$ ($\bar{b}$ constant)

End brace, $M_b=20495$ (as before)

Posts $\left\{\begin{matrix}Cc\\Dd\end{matrix}\right\}=W_p=18174.$

For these posts $\frac{l}{d}=28$ and,

$W_p(\cos. 2i+m')=18174(1+\frac{1}{11}+\frac{3}{4})=33374.$

Then for economy we should have

$$W_c=W_t\cos. 2i+W_v+W_b\left(\cos. 2i+\frac{h^2}{l^2}m\right)+W_p(1+m).$$

Actually we find,

$W_c=75095<17608+18654+24901+33374=94537$

The height is too great, $h=26$ may be tried.

107. On computing, by eqs. (11) and (12), the new weights of the Whipple Truss for a height of 29′ and of the Pratt Truss for a height of 26′, we find a saving in the former of 544 pounds, and in the latter of 714 pounds over the weights of the respective trusses 28′ high.

From eq. (14) we also ascertain that the Whipple Truss, *for the diameters taken*, might have a height of $\frac{8}{10}$ foot, say over 29′ with economy. The Pratt has within a tenth of a foot of the most economical height for the dimensions given.

ERRATA IN JULY, 1878, NUMBER.—Page 81, art. 43 $(14+1\frac{1}{2})$ should be $(14+3)$.

On page 82, 2d column, line 3, for 63866 lbs., read 63886 lbs.

On page 82, 2d column, line 4, for 33693 lbs., read 38963 lbs.

A CORRESPONDENT of the *Times* writing upon tests for diamonds says: "The late Mr. Babinet of the French Institute, in his 'Etudes et Lectures (Vol. 3, p. 38), has the following: 'I shall mention a very delicate optical character that immediately draws a line of demarcation between diamonds and all colorless gems —I mean double refraction. In looking through a transparent stone at any small object, such as the point of a needle or a little hole made in a card, one sometimes perceives the object double, as if the hand held two needles, or the card had been twice perforated. Such is the case with all white or colorless gems; but never with the diamond. Every stone, therefore, that exhibits double refraction is thereby excluded from the rank of diamonds."

GEOGRAPHICAL SURVEYING.

By FRANK DE YEAUX CARPENTER, C.E., Geographer to the Geological Commission of Brazil.

Contributed to VAN NOSTRAND'S MAGAZINE.

II.

THE ODOMETER.

The distances from station to station of the meander are measured by the odometer, an implement of survey which, in some of its forms, has been long in use in Europe, and has of late years received especial attention and improvements in the reconnoissances and other geographical surveys carried on by the War Department of the United States of North America. In this service it has been adapted to the severe conditions of travel in a new country. It has been strengthened so as to withstand any shock or fall to which it may be subject. The recording apparatus is made so compact and simple that there is no danger of disarrangement there. Instead of the old laborious process of pushing it by hand, the wheel has been fitted with shafts, so as to be drawn by a mule, and so efficient is the method of attachment that the odometer can follow any route, however rough, precipitous, or narrow, that will admit of the passage of a pack-mule.

In its simplest and best form the odometer vehicle is a solitary wheel, a little more than a meter in diameter, or about the size of a light carriage-wheel. It is strongly constructed of the best material, and is braced by opposite inclinations of alternate spokes, so as to be uninjured by the heaviest jars and collisions. A pair of shafts are attached to it, and into these a strong and steady mule is firmly harnessed by straps from above and underneath. The vehicle is close in the rear of the animal, and the shafts are made short and heavy, and in this manner the wheel is preserved in a plumb or upright position as it runs, not swaying from side to side. The length of the circumference of the wheel being accurately known and the number of revolutions being recorded by the attached apparatus, it is a simple matter to learn the distance between any two points.

The recording instrument hangs in a cylindrical box which is strapped to the wheel. It consists of a mechanical combination attached to a heavy block of metal, whose center of gravity is at one side of the axis to which it is suspended. As it is free to revolve upon this axis it always maintains a vertical position, while its box turns with the wheel, and the apparatus scores the number of revolutions, of which it is capable of recording 9900, or a distance of about forty kilometers, when it begins anew.

USEFULNESS OF THE ODOMETER.

This detailed description of the odometer is in accordance with the promise, made in the early part of this article, to dwell upon the novel features of this work, even to the exclusion and apparent neglect of others, already well-known, which are really of greater importance. Still it would be difficult to over-estimate the usefulness and practical value of this instrument. It requires but little technical knowledge to use it and to conduct the meander survey which accompanies it, and any person educated in the simplest rudiments of surveying, is competent for this kind of work.

For this reason every party of scientific exploration and reconnoissance, every preliminary survey for railways, and every marching body of troops should consider its outfit incomplete without the implements of an odometric survey. Aside from the mass of notes and sketches that would be accumulated by them, and the itinerary maps that would result, in the item of distances alone, the country would be more than repaid for the cost of these surveys. As a means of mensuration the odometer will determine distances *en route*, as the wagon travels, more truthfully than the chain itself. These, being published, are of profit, not only to the ordinary traveler, but also to the general government, whose agents and officials, in one capacity or another, are constantly passing to and fro.

ERRORS OF THE ODOMETRIC SURVEY.

Nor is there any very great error in the ordinary surveys which the odometer is likely to be called upon to perform. Having the geographical positions of two towns forty kilometres apart, they may be connected by an odometric survey, the plot of which can be adjusted between these two positions so that no intermediate points will be appreciably out of place on a map of the usual scale. Since this is a map for practical use and for the public good, it fulfills its purpose as well as if its distances had been measured by the most refined methods.

The great objection to its use is the tendency towards the accumulation of error in an odometric meander, and the farther it is from the known point which is its origin, the greater is the probable error of any position determined by it. Therefore, in a prolonged journey, or in a general survey of the country, the odometric position should frequently be verified, or checked and rectified, by connection with known points. This can be accomplished by making a station at some point on a railway, boundary, or other line of accurate survey ; by astronomical observation, which, however, if taken with a sextant, is often less reliable than the meander itself, or by making a meander station dependent upon the accompanying triangulation, by means of the three point problem. The last method, which is by far the most reliable, will be explained further on.

ERROR OF DIRECTION.

The meander is affected by error of two kinds, of direction, and of distance. The former, in its most serious nature, is incurred in the survey of a tortuous valley, whose general course must be accepted, or in crossing a timbered country, or a pathless plain, where the surveyor is in a constant state of uncertainty as to whither he is to go, or, taking a back sight, as to whence he has come. Sometimes the engineer is obliged to keep his eye on the sun and get a general idea of the course from that. Or, in traversing a dense forest, he may find himself compelled to resort to the paradox of sighting upon a sound; that is, he allows the pack-train to keep a certain distance in advance, and from time to time he directs his telescope to the tinkling of the bell which is carried by the horse that leads the train. It must be confessed that these make-shifts are loose methods of survey, but they are better than none, since they give the prominent directions and the distances between streams, divides, etc., and months afterwards, when the engineer comes to make the map and lay down upon it the trail of that day's march, he will find the poorest and most incomplete notes more reliable than his present memory and judgment.

Even under the most favorable circumstances it will seldom be possible to direct the telescope with greater precision than to the nearest degree, nor, as a consequence, will it ever be worth while to record any fraction of a revolution in the odometer. A road does not usually change direction by an abrupt angle, but by a gradual curve, and the bearing is made approximately tangent to that curve. Or, in the survey of a stream, it is not known on which side the trail will run at some point a kilometer in advance, and so the approximate center of the valley is accepted. But if there should be a solitary tree, bush, house, rock, or other prominent object fortunately situated for a station, the course will be made closely tangent to that, a reading of instruments will be taken upon arriving there, and, going on to the next station, the engineer will take a back-sight to the same point. In general the system of back-sights will be found more satisfactory than that of foresights, as it is easier, on a strange route, to tell whence you have come than to decide where you are going.

ERROR OF DISTANCE.

This error of direction, it will be seen, is thrown by the law of chance alternately to the right and left of the true line, and so has a tendency in its elements towards mutual compensation, and in a measure it corrects itself. But not so the error of distance, which is always plus, and cumulatively so. The test of the odometer wheel, by which its number of revolutions per kilometer is ascertained, is made upon a level surface and along a staked alignment, giving a result almost absolutely correct. In practice, however, the vehicle climbs acclivities of every grade, tacks hither and

thither as it follows the trail up the mountain, winds incessantly in its route through the forest, and is disturbed by frequent jolts and collisions along the rocky flow of the canon. In a theoretical traverse the straight line between any two stations is determined, but in an odometer survey the measuring implement usually follows a beaten path, and the route distance, by road or trail, is rarely the shortest distance between two points. Hence, an "overrun" in its record, which can only be remedied, and that approximately, by the judgment of the surveyor, who is taught by experience to estimate very closely the surplus in a given run, and who applies a correction accordingly.

Still, to such perfection has the odometer survey been brought, that it is a common occurrence for a skilled worker to meander a closed circuit of one hundred kilometers, and plotting the route, to find the plot also close within a small fraction of a kilometer. Even this error, being judiciously distributed in the process of adjustment, different weights being assigned to different runs, according to their probable accuracy, may be reduced so as to be practically imperceptible.

OCCURRENCE OF MEANDER STATIONS.

No general rule can be given for the frequency of meander stations, but in ordinary country they will average perhaps one to the kilometer. In this all will depend upon local circumstances and exigencies. In the survey of a long and hidden valley, affording no opportunity for checks, especial care must be taken to preserve the integrity of the meander, and the stations must be especially frequent; but in a survey by a direct line across the plain two or three stations a day may be sufficient. In a winding path up a mountain side a dozen stations may be necessary if there are no chances for checks; but if the ends of the trail, at the top and bottom of the mountain, can be located by the three-point problem, the intermediate route can be neglected, being, at most sketched in by the eye.

There are two considerations to govern the occurrence of stations; first, to preserve the continued accuracy of the survey, and second, to note the local geographical features which may be encountered. For the latter purpose stations will be made at the center of every village, at every country-house of importance, at the crossing and divergence of streams, roads and trails, at the opening of a valley, at the foot and summit of a mountain, and at the many other geographical vantage-grounds which the practical engineer will know how to select. But in this, as in the other departments of the survey, too punctilious zeal may defeat its own interests by causing delay, and the surveyor who is too scrupulously exact in the forenoon may have to virtually abandon his task in the afternoon, in order to reach a suitable camping-ground by night.

SCOPE OF THE MEANDER SURVEY.

The zone of country considered from a meander line may extend to the farthest visible point, as a series of sights upon a mountain even twenty-five kilometers away will give its position to a close approximation; but its principal intent is the preparation of a narrow route map, the areas encompassed by whose windings will be filled in from the topographical stations. Since, from its nature and narrow scope, it is fuller and takes cognizance of objects more minute than can be noticed in the other systems, in this the engineer is liable to a charge of partiality, reproved in the early part of this article. But this is not partiality in one field at the cost of neglect in another, and the greater excellence of this work is so much clear gain. Moreover, since the meander is usually by way of roads of frequent travel, and since a map is useful, and should be excellent, exactly in proportion to the number of people who are guided by it, it is well that the meander plot should excel in completeness those almost inaccessible parts which will never be seen except by the hunter or bandit.

MAKESHIFTS IN THE SURVEY.

In a forced march of forty kilometres or more, the meteorologist and odometer recorder, the safe carriage of whose implements requires a slow and steady gait, may proceed at a walk after taking their readings at a meander station, which task will occupy them but a few minutes, while the surveyor lingers behind to make

the necessary sketches and observations, and then, riding at gallop, overtakes his comrades before the next station is reached. Many such shifts as this are known to the practical and energetic geographer, who learns to emancipate himself from too close dependence on the text-books of surveying, some of whose rules are very common-place and pedantic, and brings into play his powers of ingenuity and invention, to adapt himself to the peculiar circumstances by which he may be surrounded. If he finds himself alone, out on some trip of hasty reconnoissance, or on some hunting excursion on which he could not carry both rifle and transit, he draws from his watch pocket an aneroid, and from his saddle-bags a pocket compass or an altazimuth, and his equipment for survey is complete; as for distances, he can estimate them, or determine them by the time they take, calculating at the rate of five kilometres an hour, or, better still, by counting the steps of his horse and allowing six hundred double paces for a kilometre.

In a geological survey of Brazil very much of the travel and exploration is necessarily done by water, as the outcrop of the various formations is most favorably shown upon the banks of the rivers, along which there is frequently no passable route by land. Here the stadia may be used, provided there are two or more boats in the party, or, in the less important instances, the methods of obtaining distances by estimation or by time would have to suffice. In either case the surveyor should lose no opportunity to emerge from the trough of the stream, or to ascend some eminence, and insure his position by observations upon three or more known points. Should these be wanting, he should resort to the sextant and to its use in astronomical determinations.

Since the attention of the geologist is in great part absorbed in the duties peculiar to his profession, he cannot usually carry any but the lightest and most convenient implements of survey, and since these are amply sufficient for his geological notes of dip, strike, trend, etc., it is a matter of expediency to make them answer for his geographical work as well. With the engineer, however, there rarely comes a necessity for being separated from his portable transit, which admits of being firmly set on its tripod, and from which angles, either horizontal or vertical, may be accurately read to the nearest minute. And in the general geographical plan it is wise to deprecate as far as possible the employment of unreliable pocket instruments, or of the devices for learning distances that have been detailed above. Since nothing is to be gained in time by their use, and very much may be lost in accuracy, the engineer should teach himself to consider, that any method less complete than that of the portable transit and odometer is but a temporary expedient and makeshift, serving an excellent purpose when all other means fail, but not to be relied upon as a permanent constituent of the survey.

CO-OPERATION OF THE TRIANGULATION AND MEANDER.

While the meander survey is an excellent apprenticeship for the young engineer, it should not be despised, as an occupation, by even the director of the triangulation. Humble as it is, it performs a task in the geographical plan which no system of triangulation can be relied upon to perform in a rapid work of this nature. It enables the survey to reach any point, however remote and secluded, and to determine its positions it makes the map complete in all of the details which are so useful to the traveler; and as an agent in what we may call the practical or economical branch of geography it is without an equal.

It is dependent upon the triangulation, it is true, but then the dependence is mutual. The full benefit of either can only be secured through the co-operation of the two. As without the triangulation the map is unreliable, so without the meander it is incomplete. To use a homely illustration, the triangulation may be compared to the framework of the dwelling, and the meander to the intermediate filling of wall or other substance which makes the house habitable, and is a shelter to the inmates. This frame, if its lines are true and its angles correct, is a beautiful thing for the artisan to contemplate, but without its completion of walls and furniture, it is of no real benefit to the world. In the same manner a bare triangulation scheme may

be an interesting study to the geographer himself, but to the traveling public and the people at large, it possess neither interest nor value. On the other hand, as the frame of the house is an absolute necessity to it, securing and sustaining it in its proper proportions, so is the triangulation the rigid frame work of the map and the skeleton to which the useful data of the meander are attached.

CHECKS BY THE THREE-POINT PROBLEM.

Since the meander is from its very nature so hasty and loose, the system of frequent checks can alone make it reliable, and at intervals of every few kilometres, and especially at the crossing of divides and other eminences from which there is a broad scope of country visible, connection should be made with the triangulation. Each of these stations then becomes a new initial point, at which the survey begins afresh and the error again begins to accumulate.

This rectification is accomplished by the use of the three-point problem, a geodetic determination which, as a means of locating topographical stations, and as a connecting link between the meander and the triangulation, is of the highest importance in geographical surveying. Having three triangulation stations in sight, and favorably situated, it is possible for the observer to determine his position in a few minutes of time and by the simple operation of reading the two angles included by those three stations. From these and the data pertinent to the triangulation stations he can compute his distance from them, and hence his present latitude and longitude. Or, plotting these angles from any center on a piece of tracing cloth, he can lay this upon the projected map and swing it around until each of the three plotted rays covers its proper triangulation point, when this center will indicate the position of the three-point station, as it is called. For this graphic determination not only three points, but four, and even more, if they are visible, should be observed, as a greater number facilitate the operation and insure the accuracy of the result.

This method of trilinear determinations cannot be introduced too often. A three-point station in the streets of a settlement, at the forks of a road, or at the end of a mountain range, will locate these important places, and in camp, even in the center of a broad and vacant plain, there is no more profitable manner in which the engineer can spend his leisure time, before or after dinner, than by making a three-point station there and determining his position. Every camp thus fixed is a new and reliable origin at which the meander of the next morning will begin.

A SURVEY BY THREE-POINT STATIONS ALONE.

In some cases a successful meander may be carried on by three-point stations alone, when all other means would fail. Take, for instance, the rugged shores of a lake or bay, which are inaccessible except to a man on foot or in a boat. In the mountains on the other side of the water a series of triangulation stations stand up in full view. By means of these the engineer, working his way, transit in hand, from bay to bay, and from point to point, along the water's edge, makes three-point stations at all prominent changes of curvature, and, sketching in the intermediate shore, he determines its line by tangents and intersections, and thus secures a good survey of the coast. If there are islands out in the water they may be surveyed in the same way.

If the engineer was confronted with a piece of geography like the bay and islands of Rio de Janeiro, and if there were no roads along the beach to make direct linear measurements feasible, he could extend his triangulation to include all of the prominent peaks in the vicinity, and then, by means of three-point stations, he could rapidly trace in the shoreline. As the surroundings of Rio are so broken and irregular, the triangulation points could be made so numerous, that it would be difficult to find a spot on the beach, or mainland, or island, so secluded that some three of these stations would not be visible from there.

THE MEANDER PLOT.

Every three-point station, as well as every other meander station, should partake more or less of the nature of a regular topographical station; that is, contour sketches should be kept constantly on the plotted page as it progresses, and a continuous panorama of profile views,

drawn in a separate portion of the book, should accompany the survey, so that, as some geographical features are left in the rear, others may be introduced in advance.

As from one topographical station to its neighbor, so every distance from one meander station to the next should be considered a base to be used in the location of points useful in the structure of the map. The longer this base, the more distant may be the range of these views. In case several meander stations intervene between one observation and the following, this total intermediate distance becomes what is called a broken base, but it is none the less useful for all of that. The above considerations will influence the engineer in his choice of stations, which will always be situated in such positions as may offer the best advantages for the accumulation of whatever information he most needs.

THE DECLINATION OF THE COMPASS NEEDLE.

The variation of the compass needle, or, more properly, its declination, will be carefully watched throughout the survey, and determinations of its angle will be made from time to time; these will be more than usually frequent wherever there is suspicion of some attraction immediately local, arising from the presence of magnetite or other ore of iron, basaltic rock, or other disturbing influence. These determinations are important, not only in the reduction of the meander notes taken in this vicinity, but also for the practical use, both present and future, of the country at large. In addition, their results will aid the general cause of science in its investigation of the laws of terrestrial magnetism, and in tracing the course of isogonic lines around the world.

At every triangulation, topographical, and three-point station, the observer will note the direction of magnetic north, as indicated by the pointing of the compass needle. If his instrument has a double movement in azimuth, as all should have, it is well, for the sake of convenience, to first set the zero of the graduated limb upon the same point of the vernier plate, by the upper motion, and then, by means of the lower movement, bring the north end of the needle to the zero of its circle. His initial entry in his note-book will then be "Magnetic North, 0° 00′ 00″." This direction of the telescope being referred to some line proceeding from here, whose true azimuth will be found by subsequent computation, the magnetic azimuth or declination of the needle at that place will be determined; it will simply be the difference between the true azimuth of the line, reckoned from the north point of the horizon, and its apparent azimuth, or the vernier reading which he enters in his notes.

BY DIRECT ASTRONOMICAL OBSERVATION.

The declination of the needle will also be determined directly by astronomical observation in the evening at camp. For this purpose the engineer will select such nights, clear and still, as may appear to him most favorable, and such camping places as may most urgently require this information. A star as near as possible to the pole will be chosen, as, from its greater declination, an error in the latitude of the observer's place, and, from its slower motion, an error in the time of the observation, will result in less serious errors in the azimuth; and the smaller the polar distance of the star, the more convenient will be the observation and the computations which follow, and the more exact is the result likely to be. In the northern hemisphere α *Ursæ Minoris*, or *Polaris*, is almost always used, as it is at present only about 1° 20′ from the pole, and it possesses the additional advantage of a brilliancy of the second order. But south of the equator there are no available stars so favorably situated as this. The most southern one of any considerable size is β *Hydri*, of the third magnitude, whose polar distance is a little more than twelve degrees.

This would have to be accepted in a survey of this nature in preference to any of the less brilliant stars of greater declination, as the observations would have to be made frequently by engineers of little astronomical experience, and with instruments not especially adapted to this kind of work. Indeed, it might be necessary at times to use the small meander transit for that purpose; and it is seldom that the telescopes of even the theodilites for triangulation, as now constructed, are provided with the hollow rotation axis requisite for a proper illu-

mination of the diaphragm, without which it is difficult to see both cross-hair and star, unless the latter is of conspicuous magnitude.

Knowing, at least approximately, the latitude of the place, and also the declination of the star and its hour angle at the time of observation, its azimuth angle from the south point can be computed. But as the hour angle depends upon the local time at that place, and there is great room for error there, the observer, unless he has full confidence in his ability to make an accurate time-determination, should find the approximate minute of the star's greatest elongation, and follow it with the transit thread until it reaches the dead point in its azimuth motion, where it seems to stop a few moments between its advance and retrogression. Then, being at its greatest elongation, the sine of its azimuth angle is equal to the cosine of its declination divided by the cosine of the latitude of the place.

Should the star *β Hydri* not arrive at its east or west point at a convenient hour, as at certain seasons of the year it will not, the star *Canopus*, differing in right ascension about six hours, or ∝ *Trianguli Australis*, of about sixteen hours greater right ascension, may be employed. These are respectively of the first and second magnitude, and hence are very well adapted to this purpose, but, owing to their greater polar distances, it would be necessary, in their use, for the observer to be especially sure of the correctness of his latitude.

The sun is not usually available for determinations of azimuth or time, as the engineer is generally upon the march throughout the day. The use of a star, however, admits of greater precision in the observations, while the resulting computations are less complicated, and, in the case of an azimuth determination, a south star is doubly convenient from the fact that its two daily elongations always come above the horizon, and whichever one occurs most opportunely may be used; or it may be possible at times to observe both, in which case it becomes unnecessary for the engineer to know his latitude. The same difficulty of latitude, may also be avoided by the method of equal altitudes of a star, taken at several hours before and after its meridian passage; the middle point between the two corresponding azimuths will be upon the meridian.

THE METEOROLOGIST AND HIS INSTRUMENTS.

In all of his travels the meteorologist will be the constant companion of the engineer, so as to be prepared to take observations at any point that the latter may designate. At the beginning of the field season he will be furnished with, at least, two complete sets of meteorological instruments, to be carried by himself and by others who may be appointed to assist him. Each set will be composed of a cistern barometer, an aneroid, maximum and minimum thermometers, pocket thermometers, and a psychrometer, consisting of two similar thermometers, one with its bulb capable of being moistened by the capillary attraction of a loose cord of cotton filaments leading to it from a cup of water, and the other dry, as in the ordinary instrument.

Prior to taking the field he will compare these barometers by a series of readings extending through several days, with some standard barometer whose error is known, in order to obtain the instrumental errors of the instruments at hand. Throughout the season, also, he will lose no opportunity for comparisons with any reliable barometers that may be encountered, as well as for frequent comparisons between these two. In this manner the time of any possible dislocation of the scale, or other source of error, will be determined.

As in the rough and rapid travel of a geographical survey, there is great liability to break the fragile glass tube which contains the heavy mercurial column, an extra supply of barometer tubes and mercury should be transported with the party, and also an assortment of tools and material for the filling, boiling, and fitting of a fresh tube. This is a delicate and difficult task, but it is one in which every meteorologist should be proficient. As full instructions for the use and repair of meteorological instruments have already been prepared by the Commission, it is needless to repeat them here.

METEOROLOGICAL OBSERVATIONS.

At every station of the survey, the meteorologist will read from his instru-

ments the data from which the elevation of that point may be subsequently computed. Nothing more is then needed for the precise determination of that station's position. The engineer has fixed it in latitude and longitude; the meteorologist, in its altitude above sea-level. The meteorological data will be more or less comprehensive and will be read from instruments more or less reliable, according to the geographical importance of the place at which they are taken. The more frequent the readings, and the more prolonged the series, the more trustworthy will the resulting mean be, and the less liable to be materially affected by errors of observation, and by those erratic fluctuations to which the barometer is subject, owing to the constantly varying atmospheric currents and other disturbing physical conditions to which it is exposed, and whose effect cannot be entirely eliminated by any formulas that it is possible to devise.

Beginning at the point of outfit which, on account of the work of preparation and the measurement of the base-line, may be occupied some weeks or a month, hourly readings will be taken throughout the day and night for as long a time as possible. The cistern barometers will be read, as the height of the mercurial column is the basis upon which all barometrical determinations rest. The attached thermometer will be read, to learn the temperature of the mercury, and hence what correction must be applied to reduce it to the freezing point, at which all barometrical heights are compared. The isolated thermometer will give the temperature of the surrounding atmosphere, to be used in determining the mean temperature of the stratum of air intermediate between this and the reference station. And the psychrometer will reveal the amount of aqueous vapor in the atmosphere, and the influence of its pressure upon the height of the column of mercury. In addition to these, note will also be taken of the direction and force of the wind, the condition of the sky, the proximity of storms, and other atmospherical phenomena, as this information may give the key to some abnormal barometric oscillation which would otherwise have to remain unexplained.

HORARY AND ABNORMAL OSCILLATIONS.

The hourly observations will be continued throughout the day and night for the purpose of determining the amount of the horary oscillation at that place. This horary oscillation is a somewhat regular rise and fall of the barometer, occupying a period of twenty-four hours. The range of this fluctuation in some parts of the world is so great, that its effect upon the mercurial column may equal that which would be produced by a change of fifty meters in altitude. It is such that, if the successive heights of the column be represented graphically by a curve, this curve will show two daily maxima and minima, occurring at intervals of about six hours, the morning maximum being attained at about ten o'clock A. M. This horary curve, as it is called, varies with the latitude, altitude, and climate of a place, as well as with the different portions of the year. The value of the horary variation for any hour of the day is revealed by a study of the prolonged series of observations at that place, and may be assumed to be the same for all observations taken in the vicinity of that station and in the same season of the year.

The barometer is also influenced by the abnormal oscillation, apparently resulting from the progress of great atmospheric waves across the country, affecting the mercurial column by a gradual rise of several days, followed by a period of subsidence of about an equal duration. The effect of this disturbance can be eliminated, approximately, by taking the difference of the barometric readings at the beginning and ending of any one day of its rise or fall, and considering this as its amount for that twenty-four hours, a proportional part of which will be its value for one hour.

DETERMINATION OF HEIGHTS.

To obtain the altitude of the first station of the survey, a mean of the corrected heights of the mercurial column is compared with a corresponding mean of the same hours of the same days at some permanent station, whose elevation above the sea is definitely known, as, for instance, the Imperial Observatory at Rio de Janeiro. This, by a process of computation, gives their difference of

altitude, and hence the total elevation of the point in question.

Now, making this point of outfit a reference station, at which an observer is left with meteorological instruments to be read at stated intervals throughout the day, the party takes the field, and the traveling meteorologist reads a series of barometrical and other observations at the first camp and at all others to which they may come during the season. These will be compared, as before, with synchronous* observations at the reference station, and the differences of altitude will be calculated. At every topographical station, and station of importance along the meander survey, such as villages, fazendas, mines, mountain passes, divides, etc., and at all other points that may be designated by the engineer, the meteorologist will read the cistern barometer, the watch, the thermometer, and the psychrometer, and, for the purposes of comparison, the aneroid barometer as well. These isolated observations will also be referred to the main barometrical station at a distance.

But, on the occasion of the ascent of a mountain peak from a fixed camp, better results will be obtained by considering the camp a reference station in the determination of the altitude of the mountain. This ascent will necessitate the occupancy of the neighboring camp for two nights and a day at least, and perhaps longer, while the peak may be occupied only a portion of a day, during which time, however, there will be corresponding hourly observations at camp and mountain-top. Hence the altitude of the mountain will be most truthfully ascertained by referring it, by these synchronous observations, to the camp, and then the camp, in a similar manner, to the distant reference station.

HORARY CURVES AND REFERENCE STATIONS.

Whenever the party, or a portion of it, remains stationary in camp for a few days at a time, hourly observations day and night will be taken to determine the horary curve at that place; the longer the series, the better will be the result. Since the horary variations are constantly changing with altitude, country and climate, it is important to have as frequent determinations of them as can practically be made, so that no very great distance may intervene between the place where a table of horary corrections is constructed and the place where it is used.

For a similar reason it may be deemed necessary to establish and sustain a second meteorological reference station, if the field of the season's survey should be a wide one, or if it should vary greatly in the atmospherical condition of different portions of its area. No comprehensive rule can be given to govern the number of these reference stations; all must depend upon the judgment of the director of the survey, and the resources at his command. In general, the farther the place of an observation from its reference station, the less reliable will be its result. But, as an exception, let us take the example of a broad inland plain, separated from the sea and its influences by a wall of mountains, within which, upon the plain, the reference station is situated. In this case it may be more justifiable to refer to this station a point on the plain, five hundred kilometres distant, than one just over the mountains, only one hundred kilometres away. This is owing to the widely different climatic circumstances of inland and sea-coast, resulting in meteorological conditions so dissimilar that equal amounts of pressure cannot be relied upon as an indication of equal thickness of the atmospheric envelope.

THE ANEROID BAROMETER.

At the many stations of the meander survey that are comparatively unimportant, and that are occupied for a few minutes only, it will suffice for the meteorologist to read only his aneroid, watch, and thermometer. Although the aneroid is not a reliable instrument, yet it serves an excellent purpose where rapid and approximate work is sufficient. Since its principal use is in obtaining profiles of the meander routes, which will enable the engineer to properly distribute the

* It is well to distinguish between the meanings, as now understood, of the two words "synchronous" and "simultaneous." The term "simultaneous" is applied to observations which are made at the same absolute instant of time, as, for instance, upon the occultations and eclipses of the heavenly bodies. Synchronous observations are taken at the same hour of the day, local time, irrespective of the difference of longitude between the two stations. Therefore, observations can be both simultaneous and synchronous only when the observers are upon the same meridian. The word "simultaneous" belongs especially to the province of astronomy, whilst "synchronous" is most frequently used in connection with the phenomena of physical geography.

contour lines upon his map, and since, farther, the error of an aneroid will rarely exceed the vertical distance between two of these contours, the resulting inaccuracy upon the plot will be quite inappreciable.

The aneroid is to the cistern barometer what the meander is to the triangulation, that is, a means of filling in, which, while costing but little extra effort, is productive of very valuable results. The engineer who rejects the meander and the aneroid because they are not rigidly exact in their functions, will find himself reduced to the necessity of tracing in the roads and streams of his map, locating many of the villages, cross-roads, etc., and drawing in the contours from his judgment and memory alone; and it is safe to say that the conjectures of the most able and trained topographical intellect are by far less reliable than the figures of those humble instruments, the aneroid and odometer, when judiciously used.

At every camp the aneroids are compared with the cistern barometer, their scales are adjusted in compensation for any error that may have crept in, and the vertical element of the survey starts from a new and true datum plane when the march is resumed. At the end of the day's journey, also, they are immediately compared again, and the error accumulated throughout the day is noted, and, by a process of distribution along the day's profile, may be reduced to a minimum. Before and after every side trip, reconnoissance, or ascent of mountain, the aneroid is compared with the mercurial barometer, and thus, by a continual and careful watch over it, it may be relied upon to give results not seriously in error. But if left to itself and unchecked for any great length of time, or for any great distance of journey, or great change in altitude, this fickle instrument may continue to go astray, by a shifting of its scale, exhaustion of its spring, or from other causes, until its readings are hundreds of meters too high or too low. Even then, however, it may be of use to the geographer in drawing in the relief of the country, as the discrepancy is usually of gradual growth, and the relative altitudes during the progress of the survey, as, for instance, the height of a bluff above the neighboring valley, are sufficiently exact to be of much assistance to him in his plotting.

BAROMETRICAL RESULTS.

As to the reliability of altitudes determined by the cistern barometer, evidences and opinions differ, but those persons who are most thoroughly informed are generally the most lenient in their acceptation of results. Colonel Williamson, of the United States Army, who has probably given more intelligent study to the barometer than any other man, has compiled a table of the maximum errors which occur in numerous series of observations taken both in North America and Europe. Among these are many that exceed fifty meters in amount, and he assumes that the barometer under similar circumstances will be liable to equal errors elsewhere. These, however, are not to be considered as representing the probable error of barometrical results, they are rather the extreme limits of probable error, and may be taken as the error to which the barometer is liable under certain rare and very unfavorable conditions. While exact truth concerning altitudes is something which no barometer can be expected to tell, and while it is never safe to guarantee the accuracy of such a determination, even within many meters, yet when barometrical work is prosecuted judiciously and systematically, as it would be in this survey, and based upon formulas which represent the latest and most complete knowledge of meteorology, its tendency is to give results that are seldom more than a few meters wrong.

It is often difficult for the popular mind to comprehend how an error of meters may be inevitable in some of the processes of barometric hypsometry. Since the scale of a barometer may be read to a thousandth of an inch, and that amount of variation is supposed to correspond to a change of one foot in altitude, it would naturally be thought possible to determine the elevation of a place to the nearest foot. But this difficulty will be better understood when it is remembered that the barometrical measurement of the difference of altitude between two places depends upon the determination of the weights of a column of atmosphere at each of these stations;

that this atmosphere is in a state of constant change and perturbation, its pressure being modified by variations of heat and cold, storm and calm, and the absence and presence of moisture throughout different portions of its extent; and that, while some of these conditions are quite unknown to the observer, those that are apparent to him can be but incompletely compensated for. Therefore, since barometric hypsometry is not one of the exact sciences, but is affected by every change in the wind and weather, any determination of altitude that is true within a meter, is as much a source of surprise as of gratification to the meteorologist, who will be obliged to confess that this closeness could scarcely be possible without some coincidence and accidental equilibrium in the disturbing influences to which the barometer is subject.

DIFFICULTIES IN BAROMETRIC HYPSOMETRY.

At times men of little experience may have to be accepted as meteorologists. They work, perhaps, under the embarrassments of exposure, fatigue, and a lack of appreciation of the responsibilities that rest upon them. It may be long before they can be taught to regard those niceties of barometrical work without which it cannot be truly successful; although there is but little hope of determining an altitude to the single foot, yet they have to learn that this is no reason for neglecting that thousandth of an inch which corresponds to a foot. Their instruments may be out of order, owing to the hardships of travel to which they are exposed; the readings may have to be referred to a distant station of very dissimilar physical surroundings; or they may have been taken upon the top of a lofty mountain, in a belt of the atmosphere with meteorological phenomena quite different from those properties of the lower strata of the air, for which our formulas were framed.

These are some of the sources of error which may have conspired to vitiate those results which are fifty meters or more at fault. In Brazil, however, it is hardly necessary to anticipate discrepancies so great as this, since it is a country in which no very great change of altitude is possible, violent and phenomenal storms are not frequent, and the atmosphere is of comparatively steady temperature, and not liable to sudden transitions from one extreme to the other.

BAROMETRIC FORMULAS.

Even if the observations have been made under the most favorable conditions of atmosphere, elevation and location, and are perfect as far as human intelligence can make them so, that is, free from all personal and instrumental errors, there yet remains a consideration which may materially affect the completed altitude. The same observations, reduced by different formulas, will give results in some cases widely different, the discrepancy between the returns of two well-authorized methods of computation frequently amounting to the sum of the real errors of both; this is exemplified in the following determination of the height of Corcovado, in which one system of reduction gives an altitude above the true one, and the other places it too low.

The barometric formula is composed of several terms, each of which is a combination of some physical constants, such as the relative weight of air and mercury, or the variation of gravity with latitude, and some of the barometrical data, as the temperature or moisture of the atmosphere. Of these formulas, there are two general classes, based upon the equations of Laplace and Bessel. Not only do they differ in those constant quantities upon which all barometrical determinations must depend, but also in the presence or absence of an entire term, as the formula of Bessel has a separate factor as a correction for the humidity of the air, while Laplace includes the influence of the aqueous vapor with that of temperature.

Thus it will be seen that the formula of Laplace is more convenient, while that of Bessel is more complete. The scientific world has found it difficult to choose between them, and while Delcros, Guyot, and others have accepted the formula of Laplace, that of Bessel has been adopted by Plantamour, Williamson, and others. But it is admitted, even by those who are in favor of the former method, that the constants in use in Bessel's formula, as modified by the more recent arrangement of Plantamour, are later and more

reliable than those accepted by Laplace, and there is also a prevalent opinion among scientists that some accuracy has been sacrificed to convenience in Laplace's method, a concession which it may sometimes be justifiable to make in the application of a formula, but never in its construction.

The advocates of each system have published examples showing the close accordance of their results with altitudes determined trigonometrically or by spirit-level. But as the number of these remarkable coincidences is about equal on each side, and as in each instance the observations would have given results considerably wrong by the application of the other formula, they prove simply two things; first, that they are coincidences, and that to certain cases the method of Laplace is most applicable, while to others that of Plantamour will yield better returns, and second, that it is quite impossible to devise any formula that will yield an accurate solution of all problems in the barometrical measurement of heights.

Since there seems to be a preponderance of evidence and a growing disposition in favor of Plantamour's formula, it has already been adopted by the Geological Commission as a basis for its barometrical work, and its several terms have been developed into tables for the convenient computation of altitudes. After the preparation of those tables and as a test example with which to prove their efficacy, the height of Corcovado Peak was determined barometrically with the following results:

	Metres.
Altitude of Corcovado, by tables of the commission, based upon Plantamour's formula	705.84
By Laplace's formula	702.15
Determined by triangulation	704.74
	Metres.
Error by Plantamour's formula	+1.10
" Laplace's "	−2.59
Discrepancy between the two	3.69

The foregoing is a very creditable and satisfactory barometrical result, and is one more argument in favor of the use of Plantamour's complete formula.

ALTITUDES BY VERTICAL ANGLES.

As a supplement to the barometric hypsometry, every theodolite, whether for meanders or triangulation, is fitted with a vertical circle, from which to read the angles of elevation and depression of those points which are located by intersections, in order to compute the heights of the same. From this angle and the horizontal distance between any two peaks, their apparent difference of altitude is obtained by a trigonometrical calculation, and then a correction is applied for earth's curvature and refraction. In the field these angles are recorded as plus or minus, according as the objective point is above or below the observer's station, whose altitude is invariably determined by barometric readings.

In this manner the heights of hundreds of points throughout the field of survey are found with an accuracy nearly equal to that of the peak from which the angle is taken. Indeed, a mean altitude derived from the three angles of elevation, read from three different triangulation stations, will give the altitude of the point of intersection with less probable error than that of either of the mountains from which it was derived.

METEOROLOGY IN THE SOUTHERN HEMISPHERE.

Brazil stands almost alone as a great civilized country lying in the Southern hemisphere. It is comprehensive in its latitude, reaching from north of the equator far into the south temperate zone. From this unique and favorable position upon the earth's surface, as well as from the liberal patronage bestowed by its government upon the development of science, it needs no prophetic eye to see that this empire is destined to become one of the busiest and most fruitful fields of scientific research. Especially is this the case in the investigation of those great questions concerning the terrestial shape and dimensions, and those others, still more numerous, which from the form of the earth, or from other and unknown causes, vary with geographical position. Important among the latter is the science of meteorology, whose general laws are not the same all the world over, but which are largely influenced by latitude and by proximity to either pole.

The following extract from Colonel Williamson's valuable treatise on the

barometer and its uses, will illustrate the absence and the need of meteorological observations south of the equator:

"It has been determined by actual observations, and confirmed by theory, that the sea-level pressure varies in different latitudes by a definite law, modified in practice by local peculiarities of climate. It has been found that the mean barometric pressure is less in the immediate vicinity of the equator, and it increases towards the north to between latitude 30° and 35° where it is greatest. It then gradually decreases to about latitude 60°, and from there towards the north pole there is a slight increase. In the southern hemisphere, where the observations have been less numerous, the mean pressure seems to increase to between 20° and 30° of south latitude, when it gradually decreases to about 42°, and then commences a remarkable fall, so that towards the south pole, the mean pressure is said to be less than 29 inches."*

In the table of mean heights of the barometer at the sea-level, given in various works on meteorology, there are but two stations south of the equator; these are Rio de Janeiro and the Cape of Good Hope. In north latitude, however, the list comprises more than thirty places at which this determination has been satisfactorily accomplished, by years of observations, and these are favorably situated at intervals between the equator and the pole.

Again, while the horary oscillation in the atmospheric pressure is greatest near the equator, and diminishes thence each way to the poles, the abnormal oscillation is least in regions of small latitude, and increases with the distance from the equator. As the latter is the more incomprehensible and less regular of the two, and consequently the greater source of error, it would appear that, in general, barometrical work would be most reliable in tropical regions, and hence this system of hypsometry would be especially applicable to Brazil. And, in addition to their immediate and practical use in the construction of maps, the meteorological results of a survey of the proposed nature, taken at low and high altitudes, at the sea-coast and in the remote inland, with permanent stations at intervals where long series of observations would be accumulated, would form a basis upon which to establish the general laws of barometric fluctuation throughout this vast portion of the Southern hemisphere.

* 736.6 millimetres.

CONTINGENCIES IN THE SURVEY.

The foregoing are the general divisions and some of the novel features of the geographer's work in the field. While these are sufficient to carry the survey across any ordinary country, certain districts may be encountered in which these methods may not be easily applicable. It is impossible, in a paper of this nature and length, to foresee and provide for all of the emergencies that may arise; it is necessary for the geographer to first see his territory, and then, if he is a true engineer, he will be able to devise some means of survey which will be competent to meet the difficulties, however great they may be.

For instance, it may be asked how a survey based upon triangulation, can be carried across the smooth and unbroken table-lands of a country. The answer will be that the plains are not usually so broad that they cannot be spanned by the length of a triangle-side; and, furthermore, if there are no eminences that can be used for triangulation points, so much less is there need for this system of survey. Over the smooth plain it is possible to travel in straight lines, such being the usual character of roads in a level country, and since a meander by direct routes is reliable, the survey can proceed from one known point to the next with comparative accuracy, tracing in the rivers, lakes, and other geographical features as it goes. As a rough, mountainous country is its own remedy, furnishing a great number of advantageous stations for the survey, so, with the absence of these mountains, vanishes in great part the labors and difficulties of this work.

THE STADIA, OR TELEMETER.

Although the stadia, or *telemeter* process, is too slow for the general prosecution of a geographical survey, there may be occasional areas in which the previous methods will fail, and this will suffice. The direct linear survey of a river, by

this means, has already been mentioned. As another illustration, take the case of a valley—as, for instance, the valley of the Amazon—which is so broken with lakes, swamps, and the many channels and arms of the river, that its islands and shores cannot be reached and located by any means of direct measurement; and where, farther, the vegetation is so abundant and dense, that ordinarily no three fixed points are visible from the water's edge. Here the telemeter may be the only instrument by which the required distances may be obtained. The observer, establishing his instrument in open ground, from which triangulation stations can be seen, sends his assistant, in a boat or otherwise, to such points along the water as may be in sight. These he locates by single observations, reading the distances from the rod held by the assistant. Thus the telemeter station is referred to the observer's position, which, in its turn, can be fixed by means of three-point observations upon the triangulation stations of the bordering cliffs.

In this simple and ingenious way of determining distances by single observations, it is necessary that the diaphragm of the telescope of the observer's instrument should be fitted with two horizontal cross-wires, and that his assistant should be furnished with a graduated rod, or telemeter. Then looking through the telescope, the projection of the cross-wires upon the rod includes a certain amount of the graduation. This is a chord subtending a certain constant angle in the line of collimation, and, by a principle in geometry, this chord increases directly with its distance from the angle which it subtends.

THE PLANE TABLE.

With the use of the plane table, there comes so great a temptation to go into the details of the work, to linger over a small area, and to finish the sheets with a topographical completeness, that its too general adoption will be found to retard the progress of a geographical survey. In addition, it is cumbersome in its shape, offering a broad surface of exposure, and for that reason is not well fitted for service upon high mountain stations, where the wind is strong and storms are frequent. In its favor, however, it must be said that this instrument has been successfully employed upon the extensive geological and geographical surveys under Major J. W. Powell, of the United States, and that very favorable reports have been made concerning its usefulness. The inconvenience of its shape has been modified in this service, the table being composed of slats hinged together, so that it may be folded into a small compass for the purpose of transportation.

When, in the course of a work of this nature, there is encountered a district where the importance of the field will justify a minute and laborious survey, the plane-table will serve an excellent purpose there. It is very useful in the mapping of a populous district, the suburbs of a city, a mining region, or in the representation on large scale of a piece of topography which is interesting as a type of geological structure. It is always an easy matter for the geographer to accommodate himself and his methods to detailed surveys like the above, and it is a mistaken idea to suppose that the exploration of a province, unfits an engineer for the topographical delineation of a parish. In all work of engineering there is a constant tendency towards greater accuracy, refinement, and detail, and it is not freedom which the geographer enjoys, in neglecting the minor features of the earth's surface, but rather a necessary restraint that is imposed upon him, to keep him from sacrificing the important to the unimportant.

THE OFFICE WORK.

As for the computations and other reductions of notes which follow a field season of the survey, there is not space to discuss them here, nor is there any special need of such a discussion, as they do not differ materially from those which apply to geodetic work in general. Nor are the duties of the draughting-room greatly distinguished above the customary routine of such office work. This thing only, may be noticed, that the hand to hand struggle which the field engineer constantly sustains with the forces and obstacles of nature blunts the delicacy of his touch, and makes his hand too heavy for the fine drawing necessary in a map finished for publica-

tion, and there should be in every office a superior draughtsman who is accustomed to the use of no heavier implement than the artist's pen.

This artistic finish is bought by some sacrifice of accuracy, however, and beween the field engineer and the final draughtsman there should be few, if any, middlemen to compile and replot the work, because only the man who has seen the country can reproduce its physical characteristics with truthfulness. In every copy that is subsequently made the face of the land grows more artificial and ideal; each mountain loses its individuality of shape, and assumes a symmetrical regularity which it does not possess in nature; some of the niceties of truthful representation are magnified into exaggeration, and others are overlooked and obliterated; the bed of every cañon grows broader in each successive transcript; and the large hills grow larger as the smaller ones dwindle away. As in a popular parlor game, a whispered story, passing current from mouth to mouth throughout the round of a circle, grows strange and distorted beyond recognition, so in the successive reproductions of a map by strange hands, it loses its photographic truth of execution as the idiosyncracies of the various draughtsmen are wrought into the plan. Finally it comes to represent a country that is unnatural in its regularity, made not so much by the accidents of nature as by the design of man, and moulded by the rules of a uniform and rigid geometry.

PLOTTING THE NOTES.

It is necessary that each engineer shall plot his own notes, as he alone is familiar with their arrangement throughout his books, and only he is able to derive the full benefit from them. Therefore during the office season he will be engaged upon a contour plot of the area which he has surveyed during the preceding half of the year. Here he will collect and compile in graphic shape all of the information which lies scattered throughout the dozen note and sketch-books which represent his labors in the field. Upon this map fine drawing will not be so essential as truthful representation and the utmost accuracy of position that can be attained from the material at hand; an inaccuracy that is barely apparent upon the paper will correspond to a very large error in the field, and so a moment's oversight in the office may invalidate the scrupulous care of a day's or week's work upon the survey.

These sheets will be the basis of all the maps of the survey, no matter in what shape they may be published, and hence the urgency of having them correct in all of their positions, statements and figures, and so complete as to include every detail upon the pages of the sketch-books, down to the shape of a mountain-spur or village, or the presence of a spring of water or dwelling place. As the expense of sustaining an engineer in the field is at least double the cost of his office-work, he should confine himself to what is absolutely necessary in the collection of his notes, and then utilize even the least of these in his subsequent plotting and development of them.

CONTOUR PLOTS.

The plots will be constructed in con tour lines, as that is the only method in which the engineer can give precise expression to his information and impressions concerning the heights, slopes, and forms of the country that he has surveyed. While a map executed in hachures would be more artistic and more pleasing to the eye, it cannot be made so mathematically invariable in its conveyance of ideas, that is, it cannot be made to convey the same ideas to all persons; the bluff that would seem high to one observer would seem low to another, and the depth of shade that would represent a steep gradient to one draughtsman would stand for a moderate declivity to another, according to their peculiarities of judgment, or to the different schools of drawing in which they had been educated. The most skilled cartographer, with one of the best of hachure maps before him, would find it difficult to estimate the angle of any mountain slope, or to tell which of two neighboring peaks was the highest, unless their heights were given in figures.

In a glance at a contour plot, however, he could count the excess of lines in one of these mountains, and so compute its superior altitude; or note the number of lines in a centimeter of space, and so determine the gradient of the earth's

surface there. For this reason the contour plot is the only true basis from which subsequent maps can be made; then, no matter how many field engineers may contribute to this work, their reports will all come to the compiler and final draughtsman, written in the uniform language of lines at regular vertical intervals. Otherwise, if the plots were in hachures, this draughtsman would find it well-nigh impossible to so assimilate them that his finished map would not reveal traces of the many different hands from which it originated.

FINAL MAPS.

Unless the contour lines are so numerous and close together as to produce striking contrasts of light and shade as the slope varies, this map has no meaning to the popular eye. The ordinary observer sees in it only a maze and confusion of lines, of whose design and importance he is ignorant, and so it is of no assistance to him. Therefore, since maps are usually published for the information and guidance of the people at large, it is wise that they should be drawn with hachure shading, which gives a more intelligible but less precise picture of the country. In the construction of this, the contours of the engineer's plot are so many guide-lines to the draughtsman, who graduates the light and darkness of the shade to accord with the divergence or approach of these wavering lines.

In addition to these a map in contours may also be issued for the use of engineers, the projectors of railways, and, more especially, as a basis of the geological and resource charts, to which this system is peculiarly adapted, as its lines of equal level are of great assistance in determining the extent of the various formations, and for depicting those areas of vegetable growth which are bounded by fixed limits of altitude. The dip and strike of a bed of uniform slope being given at any one point of its outcrop, it is an easy matter to trace upon this map its line of reappearance upon the farther side of a mountain-range, or at any other point at which it may be exposed again. Or, by counting the lines of vertical equi-distance, the geologist learns the thickness of the various strata, the extent of a fault, or any other fact in geological dimensions.

REVIEW OF THIS METHOD OF SURVEY.

In this paper the writer is at a disadvantage in appearing to advocate inaccurate methods, and perhaps, at times, actuated by a desire to give a perfectly frank and honest exposé of the subject under discussion, he has magnified the amount of inaccuracy to which the operations described in these pages would be liable; at all events he has been very liberal in his allowance for probable error. Indeed, to those who have been in the habit of reading, and believing, barometrical altitudes that are given down to the tenth of a foot, or sextant determinations to the hundredth of a second, it may appear unpardonably liberal to allow for an error of meters or seconds in these classes of work, and perhaps to some it may seem indicative of professional unfitness in the engineer who would acknowledge the liability of such. But while results like the above are frequently published, their authors would be either sciolists or charlatans if they were to claim that they were absolutely reliable down to those small fractions; it is often the custom among the most conscientious and intelligent engineers to make their reports in that elaborated form, since those are the figures at which their computations finally arrived, and hence there are certain weights of probability in their favor.

In like manner, in the computations of a survey of the proposed nature, it would never be allowable to neglect or throw away any odd figure or fraction, on the plea that it was probably exceeded by the error of the whole. By following this system, not only are habits of accuracy inculcated and sustained among the assistants of a survey, but the closest possible approximation to the truth is attained.

In the ordinary branches of his profession, habits of rigid precision, at whatever cost of time and money, are the best recommendations for an engineer. In a geographical survey, however, to enforce this rule beyond the triangulation, upon which the integrity of the whole depends, and to continue it in full force throughout all of the subordinate

branches of the work, would be to make such a survey impossible in Brazil, owing to the enormous expense that would attend it. Viewed theoretically, the best of maps, even those produced by the tedious processes of the European topographical surveys, are but approximations to the truth; the question now arises as to how close it is profitable to bring this approximation. Viewed practically, the maps that would result from the proposed system of survey would be seldom, if ever, in error to a perceptible degree, and it would seem that this is the limit of accuracy beyond which this country cannot well afford to go.

To condemn a method of surveying because it is not absolutely accurate would be to condemn all of the survey of the world, and especially all of the systems of ordinary land surveying, which are so faulty that it is very seldom that a purchaser of land does not get either considerably more or less than he pays for. Still, that has not been deemed sufficient reason why all buying and selling of real estate should cease until its boundaries could be determined by the instrumentality of such rods, compensated for temperature or packed in ice, as are used in the measurement of geodetic base-lines. In one respect the proposed system is far superior to the land survey, as it is founded upon the principle of triangulation, which, securing it in its true proportions, prevents any great accumulation of error. In the United States of North America, where surveys of this nature are in active and successful operation, it has been earnestly advocated that the triangulation of the geographical survey should be made the basis of the land survey, the different triangulation stations serving as initial points from which to run the land boundaries, and it is very probable that, within a year or two, this plan will be adopted there.

There are different degrees of accuracy, each adapted to the end which it is intended to serve; this degree, explained here, is sufficient for the rapid preparation of a very useful and complete geographical map. It would not suffice for the measurement of an arc of the meridian, such as has been proposed for this empire. That is a work in which no error, however small, that is not beyond the cognizance of the human senses and judgment, can be excused or overlooked. To publish a wrong result here would be not only a national disgrace, but a misfortune to the whole world, as it is upon the shape and dimensions of the earth that many of our geodetic and other scientific formulas rest, while it is from the same source that the world derives its standard unit of length, by which the interests of all civilized people are affected. Or, if Brazil were prepared to enter into that honorable rivalry in geodetic work, in which some of the older nations are engaged, each seeking to produce instruments, methods, results, discoveries, and developments that may be in advance of everything hitherto achieved, this system of survey would not be recommended. It is not impossible, however, that, from this as a beginning, there might grow, keeping pace with the general progress of the country, a geodetic institution that would be equal to the best.

ORIGIN OF THIS SYSTEM.

The writer by no means pretends to be the inventor of the combination of methods described in these pages, although hitherto there has been but little description of them in print. An efficient system of survey cannot be the invention of any one man; it must be the outgrowth of years of practical experience, resulting in the gradual accumulation of ideas and improvements contributed by those who have been engaged upon it. This one is the result of a growth of at least a quarter of a century, and therefore is not open to the serious objection of being new and untried. During that length of time, the enterprise of geographical surveying has been receiving more and more encouragement from the government of the United States, which has wisely adopted that plan, in connection with geological and other scientific research, as a means of opening and illustrating its vast public territory.

At the present day there are actively engaged upon this duty in that country three important commissions of survey. That of Dr. F. V. Hayden, geologist in charge, is known throughout the world by its extensive and important work, not

only in geology and geography, but in all their kindred sciences as well. A second is under Major J. W. Powell, the intelligent geologist and intrepid explorer who was the first to descend the great cañon of the Colorado River. Another, more strictly geographical in its nature, is under the auspices of the War Department, and is conducted by Lieut. George M. Wheeler, an officer of enviable reputation in the United States Corps of Engineers. While the general plan is much the same throughout these three commissions, it is especially to his former associates, the geographers and officers of the last-named organization, that the writer wishes to acknowledge his indebtedness for whatsoever of value there may be in this paper.

BRAZIL AND THE UNITED STATES.

Although, as has been stated heretofore, it is not wise for any nation to copy, blindly, and without adaptation to its own peculiar needs, the system of survey employed by any other country, yet it would seem that the processes that are fitted to the United States would require but little modification to be adapted to use in Brazil, so analogous are the two countries in many respects. They have equal amounts of territory as near as may be, but, peopling this territory, there are four times as many inhabitants in the United States as there are in Brazil; thus it would seem that the methods that are deemed sufficient for the former would certainly suffice for the latter. In each country the population diminishes from a thickly-settled seacoast back into an uncivilized and almost unknown interior. In each of these there is a great amount of wild land which the government is anxious to open to colonization and cultivation. To expose and popularize the natural wealth of this public domain, the U. S. Government resorted to the plan of scientific surveys, to which the Geological Commission of Brazil is very similar in all respects, and so efficiently have they accomplished their purpose that it has become a noticeable fact in the cartography of the United States that its maps of some of the remote and unsettled districts of the Rocky Mountains are superior to those of its oldest and richest States, and, therefore, there are now plans on foot looking to the extension of these geographical surveys over the entire surface of the country.

As the American manner of railway-building, more expeditious and involving less first cost than the European methods, has been found practicable in Brazil, in some instances, in which all other plans would fail, so with this question of geographical surveys, it may prove to be the American system or none.

RESULTS OF THIS SYSTEM.

Considering now the results that could be expected from such a geographical survey of Brazil, this question can be best answered by referring to areas surveyed in the same manner in the United States. From Lieut. Wheeler's annual report, which the writer has before him, it appears that in six years' continuance of his commission an approximate extent of 800,000 square kilometers has been surveyed. Allowing an average of five parties in the field during that time, the season's work of one engineer reduces itself to about 25,000 square kilometers. Allowing proportional returns from the various other geographical surveys at present in commission, or that have been in existence during the last ten years in the western portion of the United States, it appears that one-third of the area of that great country has been thus surveyed in that period.

This is at a total expenditure which, while including the cost of all other concomitant scientific labors, to which the geographical work has been in large part incidental and tributary, has never exceeded four hundred contos ($ 200,000) per year. There is probably no other department of public enterprise which has yielded so extensive and valuable returns for an equal amount of money.

AN ESTIMATE FOR ONE SEASON.

In general, an area of from 10,000 to 30,000 square kilometers, varying according to the geographical nature of the country, is assigned to each party for a season of four, five, or six months, and its ability to satisfactorily cover that district in that time is conceded. To illustrate the possibility of such rapid progress, let us take a typical area of 20,000 square kilometers and see what can be done with it by one party and

one geographer in one season's work of six months in duration. Of this time the first month will be consumed in the measurement and development of the base, and in other preparation. Of the remaining period one month more will perhaps be lost in unavoidable delays resulting from storms or other causes. There will then remain four months, which, at twenty-five available days in each, will afford one hundred days for active service in the field.

Allow one half of these days for the meander survey, and the other half for the occupation of mountain stations. Fifty mountain stations will thus result, and, in addition to these, there will be a topographical station either upon or adjacent to each day's meander. So there are one hundred triangulation and topographical stations distributed at judicious intervals over this territory. That is, there is one for every two hundred square kilometers of ground, or, typically, they are but about fourteen kilometers apart, and the piece of country to be sketched in contours need not extend more than seven kilometers in each direction; this estimate ignores the meander surveys, to which fifty days of the season will be devoted, and by which these stations will be separated and surrounded.

At twenty-five kilometres a day, a very reasonable allowance, the total distance of meander route will be 1250 kilometres. This distance would reach across our area nine times, cutting it into strips of sixteen kilometres in width. Hence, in order to include the entire country from this survey, the typical zone of each meander would not reach more than eight kilometres on either side of its path; but, since it would be superfluous to sketch from this base the country in the immediate vicinity of the mountain stations, these plots *en route* need never extend more than four kilometres from the central line. Of course, in practice, these surveys will not be thus distributed in straight lines at equal distances apart, but will communicate, intersect, and duplicate in every possible way. Still the meander will serve its original purpose of penetrating those regions and traversing those border-lands that are remote from the mountain stations, and will trace out the roads, trails, and important streams, whose entire length in this area will not be likely to exceed 1250 kilometres.

Returning to the office at the end of the season, the engineer will have material enough to make a plot of the country on a scale of one centimetre to the kilometre ($\frac{1}{100\,000}$), or one-half a centimetre to the kilometre ($\frac{1}{200\,000}$). Or, to put this statement with more precision, he will have so much and so detailed materetial, that he will not be able to portray it conveniently and intelligibly on a scale of less than $\frac{1}{200\,000}$. But when the final draughtsman comes to copy these plots, he may condense them, if it be thought expedient, to proportions of $\frac{1}{100\,000}$, or even smaller. On the oth er hand, portions of this area may be plotted upon a much larger plan than any here noticed, should such be found necessary for the clear and complete geographical and geological representation of the same.

EUROPEAN SURVEYS.

Now in contradistinction to the above showing, let us take up the reports of some European surveys. In Prussia, 12,000 square kilometers, a little more or less, are surveyed annually, at a cost of 800,000 marks, or, as near as may be, four hundred contos of Brazilian money,* exclusive of the salaries of military assistants; notice that in the United States, with a total annual appropriation not greater than this, at least 300,000 square kilometers are geographically surveyed each year, this territory being studied at the same time by the geologist, the chemist and the naturalist.

Upon the Ordnance Survey of Great Britain there were over 1800 assistants and employés engaged during the year of 1874; the total area surveyed by them was not more than 8,000 square kilometers. With the methods in use in Austria an experienced topographer can survey in one field season of six months five hundred square kilometers at the farthest. In Switzerland the topography is in large part done by contract, and it alone, exclusive of triangulation and publication, costs 700 or 800 francs per square stunde, or about twenty-two mil reis† per square

* A conto of reis, in Brazil, is equal to about five hundred American dollars, or a hundred pounds sterling.
† Eleven American dollars.

kilometer. So with the surveys of Italy, Spain, Sweden, and the other European countries of comparatively small extent; they are so slow, detailed, and withal so expensive as to be inapplicable to the great empire of Brazil.

AN ADVANTAGEOUS DEVELOPMENT.

So vast is the extent of this empire that the idea of a geographical survey of its territory, as a whole, is an astounding one, and is liable, in itself, to forbid all further consideration of the subject. But this plan does not necessarily imply the regular extension of this survey over the whole country, irrespective of population and wealth. On the contrary it would devote itself at first to such areas as, from geological or other economical reasons, might most urgently require it, and a region of especial interest to the geologist would be surveyed first and with especial care, to the neglect or even exclusion of those great stretches of country whose structure is unvaried and monotonous. In a few conditions of its plan, as, for instance, in the system adopted in the projection of its maps, it might provide for any possible ultimate extension, but in other respects it could operate with equal facility, in whatever districts might be assigned to it.

Nor does this plan imply the necessity of any great outlay at the beginning, but would ask to start upon a small scale at first, with a view to gradual growth as it proved itself worthy of encouragement. As the aim of this project would be not only the production of much-needed maps, but also the introduction of these methods of survey from abroad, and the training of Brazilian engineers in the use of the same, any very extensive initial basis would prove not only embarrassing at first but also probably disastrous in the end. A survey inaugurated upon a grandiose scale is too liable to exhaust the patience and liberality of its official patrons before it can exhibit results apparently equivalent to the expenditure that it has caused, and the frequent fate of such enterprises is that they are discontinued at about the time when, their organization being successfully completed, they are prepared to enter upon an area of efficient and fruitful labor; hence, all of the expense of organization and other preliminaries becomes a total loss to the government.

On the other hand, some of the most important surveys of the world have arisen from humble beginnings. Such an enterprise educates its own members, the assistant engineer of one season becoming the engineer of the next, and so on. It develops gradually and with a healthy growth, perfecting its own methods, and always experimenting upon a small scale, so that it is never liable to serious disaster. And, above all, by its early production and exhibition of results commensurate with its size, and with its cost, which is insignificant at first, it buys the right to be continued, encouraged and increased from year to year.

A GEOLOGICAL AND GEOGRAPHICAL SURVEY.

There are two very good arguments for such a geographical survey in connection with the Geological Commission of Brazil; first, its necessity to the geological survey, as explained in the early part of this paper; and second, because in such a connection it can work most economically and profitably. With a combination of these elements comes much valuable co-operation between the representatives of the various branches of science, and this is constantly acting to lessen the expense and increase the returns of such a survey. For instance, as the meteorologist of the engineering corps, an assistant with some acquaintance with geology, could be chosen. As his meteorological duties upon the march would be but light, he could devote much of his time to a geological study of the road, leaving the regular geologist at liberty to go from camp to camp by any other route that he might select. Again, the meteorologist, or even the engineer himself, may make stratigraphical sketches upon every mountain, and bring specimens of rock from the same, while the geologist is away upon some detour to regions of interest in another direction.

Or, reversing this illustration, the geologist, whose profession is so closely allied to that of the geographer, is constantly making notes of direction, distance, slope, and altitude, which are of the highest importance and use in the

construction of a map. These are lost to the world if there is not an accompanying geographical survey into whose plots they may be assimilated.

In witness of the sympathy with which the present members of the Geological Commission regard geographical work, and of their skill in the prosecution of the same, the writer would mention their intelligent and extensive surveys of the valley of the Amazon, from Monte Alegre westwards, and of its tributary, the Trombetas; of the island of Fernando de Noronha; and of many localities along the Atlantic coast and elsewhere in the empire. These are evidences of a willingness and an ability to collect geographical information, which, in themselves, assure the success of a system of geographical surveying in connection with the Geological Commission of Brazil.

ON THE PRESENT AND FUTURE WORK OF ENGINEERS IN REFERENCE TO PUBLIC HEALTH.*

By Mr. W. DONALDSON, M. A.

From "The Builder."

Intermittent downward filtration by irrigation over wide areas affords the only means of readily overcoming all the difficulties of sewage purification. Purification by continuous drenching of the land, generally called intermittent downward filtration, cannot be successfully carried out without the use of settling-tanks; that is, not without the necessity of piling up heaps of sewage sludge which has very little manurial value. The getting rid of this sludge must, therefore, entail a yearly loss. It is true that on many, probably on the majority of irrigation farms where utilization and purification are combined, these tanks are used for the clarification of the sewage before it is turned on to the land, but there is, however, not the least necessity for their use. If the sewage is kept in motion, the fine sediment is deposited evenly over the surface of the land during the process of flowing, and does not leave any visible indications of its presence, if there is an adequate area of land under irrigation. It is, of course, necessary to separate all solid bodies from the sewage by means of screens, but the total of these screenings is very small. At Reading, including the deposit of heavy sand in the screening tanks, the average daily quantity does not exceed three-quarters of a cubic foot per thousand, but at Reading the duplicate system is strictly carried out, and the sanitary authority has not to deal with the road grit nuisance.

Colonel Jones has adopted these settling-tanks on the Havod-y-Wern Farm, and is now engaged experimenting on the sewage sludge with the hopes of making it salable at a profit. He may possibly find a profitable market for the small quantity deposited in the tanks at Wrexham, but his success will only be partial. Until manure made from sludge can be sold at a price which will admit of carriage to a long distance, the use of settling-tanks must entail a yearly loss.

In my opinion, the want of success on irrigation farms has been in no inconsiderable degree owing to the half-hearted way in which the advocates of utilization have taken up the question. They ought to have regarded purification as quite a secondary consideration, because utilization must necessarily accomplish successful purification. The problem which they have hitherto attempted to solve has still been, how few acres will effectually purify the sewage of 1,000 people? The exact converse ought to have engaged the whole of their attention, how many acres will the sewage of 1,000 people effectually fertilize. The nuisances occasionally experienced on sewage farms, which are the main cause of the difficulty of acquiring land, need never occur except in those cases in which the minimum standard of acreage requisite for purification has been adopted.

* Abstract of an Address before the Sanitary Institute.

Sir Joseph Bazalgette at the discussion by the Sanitary Institute in March, 1877, upon the mode of treating town sewage, arguing from the example of London, came to the conclusion that it would not be possible to obtain land in the neighborhood of large towns in sufficient quantity and suitable quality and free from residences, for the purpose of sewage farming. He comes to this conclusion because London with a population of 4,000,000 would require an area of sixty square miles, which, expressed in another way, is an area less than eight miles square. London is, however, about ten times larger than any other town in the kingdom, so that arguments against the adoption of irrigation derived from the example of London, even if well founded, are not applicable to any other case. In my opinion, however, the argument is not in any other respect well founded. Surely in a food-importing country like England, the more acres the sewage manure will not only fertilize, but render at least doubly more productive than they can be made by any other manure, the better for the people. It is not necessary that the area required for irrigation should be either in the immediate neighborhood of the town from which the sewage has been sent, or free from residences. If a sufficient area is used, no nuisance will be occasioned, and sentimental fears on that head can easily be allayed by interposing a belt of unirrigated land.

If the Town Council of Manchester can bring water from Thirlmere to Lancashire and sell it at a profit, it is clear that sewage may be conveyed to an equal distance and also sold at a profit, if its commercial value is equal to that of the water. For the purpose of comparing the values of the two commodities we must not adopt as the standard of the value of the water the price at which it is sold, after having been distributed throughout the district to each set of premises, but what it is worth in the service reservoirs. In order to ascertain its value in the service reservoirs we must deduct the cost of distribution, which includes nearly all the cost of management and maintenance, not from the price at which it is sold for household purposes, but from that at which it is sold in large quantities for commercial purposes, because Waterworks Companies do not sell any water at a loss. Taking all these points into consideration we cannot assign a higher value than 2d. per thousand gallons to the water in the service reservoirs previously to distribution.

In the Reports of the Rivers Pollution Commissioners the manurial value of sewage is said to vary from a maximum of 2d. per ton in dry weather to a minimum of ¼d. when the sewage is diluted with storm water. According to these estimates the value of crude sewage varies from 2¼d. to 9d. per thousand gallons.

I am well aware that you will not regard the theoretical estimates of analytical chemists as evidence of much value in support of my views as to the actual value of dry weather sewage, because it is the general opinion that this value can never be realized. I shall therefore endeavor to show you that this view of the question is erroneous, that in reality the smallest value is in all cases actually realized by the production of magnificent crops, and that the failure takes place in the next stage. The full value of the crops is not realized. Irrigation farms in the hands of practical farmers, who understand the art of making the most of the farm produce, cannot fail to pay handsome returns in hard cash, but practical farmers keep their balance-sheets to themselves.

On the basis that the sewage of 100 people can properly fertilize only one acre, and at the rate of twenty gallons per head of sewage, which is a high estimate where the separate system is in force, one acre will acquire annually 730,000 gallons. We have now to consider what that acre of land under sewage irrigation is capable of producing. One acre sown with rye grass will produce five or six crops a year,—fully sixty tons of grass. This is sold at prices varying from 10s. to 20s. according to the demand and the locality of the farm. Estimated at only 10s. per ton the gross return would be about £30 per acre. From corn and root crops the gross return is worth from £20 to £30 per acre. Against this amount is to be debited rent, taxes, working expenses, and interest on farm capital. If the land is let at an ordinary agricultural rent, £12

a year ought to cover all the yearly charges under these heads, and a balance of from £12 to £14 per acre would be left to divide into tenant's profits and payment for the sewage as a manure. If this be divided equally between them the amount paid for the sewage would be over 2d. per thousand gallons. If £3 a year per acre in addition to interest on sunk capital be considered a fair tenant's profit, the value of the sewage would on that basis be more than 3d. per thousand gallons.

In Colonel Jones's pamphlet on the Havod-y-Wern Farm it is stated that the average net profit for five successive years amounted to £3 4s. 4d. per acre. The rent paid by Colonel Jones is nearly £5 per acre, so that the rates and taxes must be proportionately heavy. As he is only tenant, he puts on the debit side a yearly sinking-fund, to recoup himself for capital sunk in permanent improvements, which amounts to about 7s. per acre; with this addition the total net profit made by Colonel Jones is about £3 11s. per acre. This, however, represents only part of the whole profit. The cows fed on the farm are owned and kept by another man, who is presumed to live on his profits, but publishes no accounts. There are only ninety-two acres, so that the profit made by the cow-keeper cannot well be less than 30s. an acre. If the rent paid by Colonel Jones had been an ordinary agricultural rent, his profits would have been increased by a deduction of fully £3 10s. from the debit side in the amount charged for rents, rates and taxes. Making these allowances, the total net profit made on the Havod-y-Wern Farm has been, on an average of five years, fully £8 per acre.

The successful disposal of sewage crops is at the very root of the whole matter. To state that there is a difficulty in finding a market for them in some cases is tantamount to saying that there is no home demand for milk, butter, cheese and beef. The produce must be consumed on the farm and converted into food for man before it is brought into the market. This work can only be successfully carried out by private enterprize. So far, therefore, as the interest of Sanitary Authorities are concerned, the only point to be considered is the question of the rent at which they will be able to let irrigated land.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The annual convention of this society was held at Boston, beginning the 18th of June and adjourning on the 22d. The discussions and the excursions to neighboring localities were carried out in accordance with the programme.

The last number of the "Transactions" contains the following papers:

156. On a new method of detecting overstrain in Iron and other metals, and, on its application in the investigation of the causes of accidents to bridges and other constructions. By Prof. R. H. Thurston.

157. Steam Engine Economy. A uniform basis for comparison. By Chas. E. Emery.

158. The Inclined Plane Railroad at Madison, Ind. Its history and operation. By M. J. Becker.

IRON AND STEEL NOTES.

Steel *v.* Iron.—There is nothing in which modern progress is better exemplified than in the manufacture of steel for all purposes for which iron was formerly used. Thanks to the inventions of Bessemer and Siemens, we have arrived at the stage, where best quality steel rails, in some cases guaranteed to remain sound during a wear of ten years, are sold at prices very little higher than ordinary iron rails. A similar result is likely to follow with respect to the plates used for boilers and shipbuilding. Steel is now produced by the Bessemer and the Siemens-Martin processes, which with a tensile strength one fourth greater than iron, gives such superiority in elongation, reduction of area at point of fracture, bending, flanging and twisting, as have not been even approximately approached by the very best Yorkshire iron at considerably higher prices. We have seen specimens, showing results which might have been expected of copper, but not of iron or steel. We are surprised at hearing that the world-renowned best Yorkshire iron seems destined to be superseded by this mild steel in the same way as steel rails have taken the place of the iron ones.

We have obtained from Messrs. John Brown and Company (Limited), some interesting information on the subject of the manufacture and the capabilities of this material manufactured at their works by the Bessemer process, and the systematic care taken in the different stages. Each heat is tested chemically and mechanically, and each plate is also tested before being sent out, thus insuring that uniformity which is so much to be desired, and preventing the possibility of any unsuitable material being supplied. For this class of steel only the best and purest pig-irons are used in the proportions which long experience and the continually repeated analyses show to be most suitable. As soon as the operation of conversion is completed, and the preliminary bending-test and the analysis of the steel show that

it is of the desired "dead-soft" temper, an ingot is hammered and rolled into plates, which are annealed and then subjected to tensile, bending and welding tests. For the tensile test, strips planed out of the plates are placed in a lever-testing machine specially constructed for this purpose, and the load is increased until the pieces are torn asunder. The strain at the point of fracture should be between twenty-six and thirty tons per square inch. If found higher than this last-named strain, the heat is not used for boiler plates. In steel within the above limits of tensile strength, the test piece, eight inches long, will be found to have stretched at least twenty per cent. before breaking, and its sectional area at the point of fracture reduced about fifty per cent.; showing very great ductility as well as great strength. For the bending test similar strips are heated to a cherry-red heat, and quenched in cold water until quite cold, and then bent over close. This they must do without signs of fracture. Other strips are heated to a welding heat and lap-welded in the same way as iron is welded, the square ends of the strips not being in any way prepared for welding. On the sample ingot satisfying all these tests, the whole heat, varying from eight to ten tons, is used for boiler plates, which may be required to weld. If only the two first tests are satisfied—which is sometimes the case—the steel is used for ship-plates or shell plates of boilers, where it is not required to weld. When the plates have been sheared to the size ordered, they are annealed, that is to say, put into a heating furnace heated slowly and uniformly and allowed to cool slowly. A strip cut off every plate is subjected to the quenching test above described, and being stamped with the corresponding consecutive number of the plate, a record is kept of its quality before being sent out. Should any one of the tests not be fully up to the standard, the plates to which they belong are rejected. Thus the quality of each plate sent out is known and approved, and the fact of the plates being sent is an assurance to the consumer that the quality has been fully ascertained to be suitable for the purpose required. We understand there has been a prejudice against steel for boilers, owing to the want of uniformity which existed in years gone by, but this uniformity is now completely obtained. In answer to our inquiries if any difference of treatment is necessary in the use of this steel in place of iron, we are informed that, like all steel, it should not be heated as much as iron for flanging and welding, and that after recent careful experiments, Lloyd's surveyors have arrived at the conclusion that plates up to $\frac{1}{2}$-inch thickness inclusive may be punched without more damage to the material than is caused by punching iron plates, but that plates above $\frac{1}{2}$ inch thick should be drilled, or, if punched, afterwards rimed at least $\frac{1}{8}$-inch, or annealed. Either of these operations will leave the material at the original strength per square inch of sectional area, and it is therefore recommended to treat all plates below $\frac{1}{2}$-inch thick when possible, as well as thicker plates, in one of the three ways described. It is also recommended that all plates which have been flanged should be annealed to restore the material to a state of rest, as the annealing will effectually remove the various and considerable strains set up by the present method of flanging the plates—by heating the plates locally first in one place and then another for flanging.

Among the samples illustrating the preceding remarks, shown us by John Brown and Co., are some very extraordinary ones. One is a $\frac{1}{2}$-inch steel plate dished cold, the inside diameter being 10 inches, and depth, $5\frac{1}{4}$ inches. A similar plate was bent five times upon itself without a crack. Another plate was punched with sixty-one holes of $\frac{1}{2}$ inches diameter, with only $\frac{1}{4}$-inch spaces, showing very little distress to the metal. Ordinary twists and bends are hardly worth quoting, but a $\frac{1}{2}$-inch square bar subjected to six complete twists without a crack is so exceptional a test that it must be mentioned. These, however, are *tours de force*. A practical fact in the same direction is that steel angles, 9 inches by 4 inches by $\frac{1}{2}$ inch, are rolled in forty feet lengths for Midland Railway coaches, and that beater-bars for thrashing machines are rolled in great numbers for Messrs. Garrett, and other eminent makers, and every satisfaction is given by the material. —*Iron*.

RAILWAY NOTES.

NEW TRANSPORTATION CAR.—The Ashbury Railway Carriage and Iron Company, Openshaw, have constructed a novel kind of railway wagon, specially adapted for conveying dead meat, fish, fruit, or other perishable goods. The vehicle, which externally resembles an ordinary wagon, is built with double walls, and the intervening space is filled with layers of non-conducting substances—namely, sawdust and paper. The whole of the interior is lined with galvanized zinc, which also composes the bars and hooks upon which the meat, &c., would be hung. Along the roof runs a semicircular chamber capable of holding twelve cwt. or fourteen cwt. of ice, and into this chamber the air is first introduced, after the freight has been deposited in the van and the door hermetically sealed. After passing through the ice, the air is forced through a receptacle filled with charcoal, which dries it, and then circulates among the contents of the wagon. It is afterwards discharged through an automatic discharge pipe. This is the first wagon of the kind built for any English railway, and it is intended for service between Scotland and London. With this contrivance meat can be kept perfectly fresh for five or six days, and in case of the market being overstocked the meat may be kept in the van, which is thus converted into a temporary storehouse. The arrangements for cooling and drying the air have been designed by Colonel W. D. Mann, of the United States army, who has had considerable experience upon the railways of America and the Continent.

CHEAPEST RAILWAY IN THE WORLD.—The cheapest railway in the world is to be

found in the peninsula of East Frisia, in the extreme north-west of Germany. The peninsula has the thinnest population anywhere to be found in central Europe, and the soil is almost completely moor. A railway was, some years ago, built with Government assistance, connecting Bremen and Oldenburg with the town of Emden; but this line had to be laid down absolutely straight, to save expenses. This left the village of Westerstead five miles from its track, to the distress of the inhabitants, who tried to persuade the Government to deviate from the straight line. When they found that all petitioning was useless, they determined to make a railway of their own. It appeared almost impossible to construct a line that would pay its expenses, among a population of ten inhabitants per square mile, wholly agricultural, exporting nothing but cattle, pigs, and the scanty produce of the soil, and importing little else but a few articles required for domestic consumption. But the parish of Westerstede may now, says the *Railway News*, boast, probably beyond challenge, of possessing and maintaining the cheapest railway in the world. The line, which is a single one throughout, is about five miles long, running from the hamlet of Ocholt, and to the village of Westerstede, the terminus here being the yard of the principal inn. It has a gauge of 2 feet 5½ inches, and the rails, made of Bessemer steel, and weighing twenty-five pounds to the yard, are of the Vignoles shape, connected by fish-plates only, so that they rest directly on the sleepers. Although the country is perfectly level, consisting principally of moorland and heath, the earthworks were not altogether unimportant, as considerable drainage works had to be carried out to protect the railway from occasional floods, to which the whole of East Friesland is liable, since it rises but little above the level of the North Sea. The line has its own earthworks, but runs for some distance close alongside the ordinary road, separated from it by a ditch and a quickset hedge. There is but one station on the line, half-way between Ocholt and Westerstede; but, strictly speaking, this is no station at all, but merely a halting place for the trains. A forester's cottage stands here, the owner of which allows intending passengers to sit down in his room and await the arrival of the trains. The rolling-stock consists of two small tender-locomotives, three passenger carriages, two closed goods vans, and four open trucks. The locomotives, four-wheeled, with a wheel base of 5 feet, and a heating surface of 172 square feet, weigh seven and a-half tons when loaded with fuel and water; they only burn peat, abundant in the district, and have, instead of a whistle, a bell, which is rung at every level crossing. The passenger carriages each hold twenty-eight passengers, sitting omnibus fashion, with a door at each end, which arrangement is necessary as the trains cannot turn, there being no turntable on the line. The working staff consists of four persons, an engine driver, a fireman, a guard, and a platelayer, their total wages not amounting to more than 13s. a-day. The entire working expenses are returned as exactly £1 9s. per diem, the items of expenditure being, besides wages, 6s. for peat-fuel, and 10s. for maintenance of permanent way, repairs, grease, and other indispensable matters. There are no buildings on the line, except a rough shed for the cover of engines and carriages at each end; nor are there any signals. The passenger fares, which are low, being 6d. first-class 4d. second-class, are collected by the guard. He also accompanies the goods trains, collecting the charges, which are 1s. for a beast, 3d. for sheep and pigs, and at the rate of 2s. per ton for general goods. Pigs are the chief article of export of the district. The company, composed entirely of inhabitants of the district, including agricultural laborers, raised a total capital of £11,200, and of this only £10,450 were disbursed in the building of the line, purchase of rolling-stock, and erection of sheds, leaving a surplus of £750, which sum was placed aside as a reserve fund. To aid in starting the undertaking, the parish of Westerstede, by vote of the communal representatives, subscribed £1500 as a gift, to be returned only in case of the repayment of the whole of the debenture capital. From the returns as yet published, it appears that, in the first seven months during which the line was open for traffic, the gross receipts came to an average of £2 8s. per diem, so that, with working expenses of £1 9s., the net earnings were at the rate of 19s. a-day.

ENGINEERING STRUCTURES.

A Great Engineering Feat.—The new railway bridge over the river Tay was opened with much ceremony on the 31st May. The first movement to bridge the Tay was made about forty years ago by the Edinburgh and Northern (afterwards the Edinburgh, Perth & Dundee) Company. It was not till 1871, however, that a project destined to be fulfilled was initiated. In 1870 the necessary Act of Parliament was obtained, and on the 8th of May of the following year the contract for the erection was signed. The contract was transferred in 1873 to Messrs. Hopkins, Gilkes & Co., of Middlesborough; and Mr. A. Grothe, who was engineer and manager to Mr. De Bergue, and had shown very great professional skill in the manner in which he proceeded to erect so gigantic a structure was continued by the new contractors, and the admirable, thoroughly substantial bridge which now spans the river is a proof of their wisdom in taking Mr. Grothe into their service. The bridge is 10,612 feet in length—or two miles and fifty-two feet—and is thus the longest railway bridge over a running stream in the world. The Victoria bridge, Montreal, comes next in respect to length, being 9194 feet, or 1418 feet shorter than the Tay bridge. A still more extraordinary bridge than either is one on the Mobile and Montgomery Railroad, called the Texas and Mobile bridge, which is fifteen miles in length; but as the greater part of it is carried over immense morasses, it cannot be fairly compared with the Tay bridge, which spans a tidal river. The bridge starts from the Fife

side of the Tay, where the land is about seventy feet above high water, and gradually rises at a gradient of 1 in 356 until the highest part of the bridge is reached, being 130 feet from the level of the rails to high-water mark The greatest altitude occurs at the center of the large spans, and from this point towards the north side there is a sharply falling gradient of 1 in 74. In the structure there are eighty-five spans of the following dimensions: eleven spans of 245 feet each, two spans of 227 feet each, one span of 166 feet, one span of 162 feet 10 inches, thirteen spans of 145 feet each, ten spans of 120 feet 3 inches each, eleven spans of 129 feet each, two spans of 87 feet each, twenty-four spans of 67 feet 6 inches each, three spans of 67 feet each, one span of 66 feet 8 inches, six spans of 28 feet 11 inches each. All the spans, with the exception of that of 166 feet, which is made by a bowstring girder, are formed of lattice girders, but in addition to these spans, there are adjoining the north end of the bridge: one span of 100 feet, bowstring girders; one span of 29 feet, plate girders. The thirteen largest girders, each being about 200 tons in weight, are in the center of the bridge, and over the navigable part of the river. The girders are arranged in continuous groups, with proper provision for expansion, and are all supported on piers of varied construction. The permanent way consists of double-headed steel rails, fished at the joints in twenty-four feet-lengths, weighing seventy five lbs. to the yard, and secured by oak keys in cast-iron chains. The chains are fixed at intervals of about three feet to longitudinal timbers seventeen inches wide, and varying in depth from seven to fourteen inches. Throughout the whole length of the bridge each rail is provided with a guard-rail to afford additional security to trains passing over the structure. The floor of the bridge consists of 3-inch planking, and is covered with a waterproof composition. On both sides of the bridge, for its whole length, a strong hand-rail is erected, and painted in a light blue color. The foundations of the piers are formed of iron cylinders, with brickwork and cement. Fourteen piers at the south side are built entirely of brick, and on rock foundation, and consist of two cylinders of nine feet six inches in diameter, connected by a wall of brickwork three feet in width. At the fourteenth pier it was found that the rock suddenly shelved away to a great depth, under beds of clay, gravel, and sand, and therefore another kind of pier had to be resorted to which would give an equally sure footing. The weight of the pier was lighted by substituting for the heavy brickwork above high water cast-iron columns, fixed together by horizontal and diagonal transverse bracing, and the cylinders were increased to fifteen feet in diameter. The whole of the piers after the fourteenth are built in this manner, but in the case of the highest pairs, supporting the 245 feet spans, they have a cylindrical base of iron and brick in cement thirty-one feet in diameter, and from forty to forty-five feet in depth, standing a few feet above high water. The whole of the cylinders supporting iron columns are finished with a coping of Carmyllie stone. The first stone was laid on the Fifeshire side on the 22nd July, 1871, and on September 25th, 1877, six years afterwards, the directors and engineers had the satisfaction of crossing over the bridge for the first time in a train. The contract price of the bridge was £217,000, but the actual cost is £350,000, the great increase being caused because of the original plans of the piers having to be departed from, and plans prepared of another description of piers adapted to the soil in the bottom of the river. The quantities of materials used in the structure are as follows:—3520 tons of cast iron, 6281 tons of malleable iron, 90,600 cubic feet of timber, 8600 of cement, 4,350,000 bricks, 27,000 cubic feet of dressed ashlar, and 355 cubic yards of rough ashlar. The engineers engaged in the construction of the bridge were: Messrs. Alfred Grothe (superintending engineer) Frederick W. Reeves, G. G. Lawrence, R. S. Jones, Theodore D. Delprat, G. D. Delprat, and Thomas Templeton. On Mr. Grothe devolved the responsibility of carrying out the works, and he has done so with remarkable success.

ORDNANCE AND NAVAL.

MONSTER ORDNANCE.—It has been known for a fortnight past that the Government was in treaty with Sir William Armstrong for the purchase of four 100-ton guns which are near completion at Elswick, but it was considered prudent to keep the negotiation secret, as there were other bidders for the monster weapons in the European market. Arrangements are now completed by which these four guns have become the property of the British nation, and in the course of two or three months they will be ready for mounting on board any ship that is prepared to carry them. It is not likely, however, that they will be placed on shipboard for some time to come, for the Admiralty have made no provision for them, neither does it appear that the present condition of naval armaments shows any demand for such mighty ordnance. The chief argument for their acquirement was the apprehension that they might become the property of another Power, and so enable it to dominate the sea. At present, although Italy has 100-ton guns for the two latest war ships, and England has ready her 80-ton guns for her Majesty's ship Inflexible, there is no armor afloat which can resist the 35-ton and 38-ton "Woolwich Infants," which have during the last few years been produced at the Royal gun-factories in the Royal Arsenal, Woolwich, and employed in the national defences by land and sea. The subject has fully engaged the attention of the Government, and the desirability of manufacturing something heavier than the 80-ton gun has been strongly advocated, but while foreign nations plate their ships with anything less than 19½ inches of iron they are regarded as at the mercy of the 800 lbs. Palliser projectile fired by the 38 ton gun, and the authorities have consequently hesitated about taking a step still further in advance. The reflection,

however, that the Inflexible, with its 24 inches of armor-plating, would be defenceless against the 100-ton guns which Italy possesses, and some other Power might have possessed, has now induced the Government to conclude the present purchase, and, furthermore, to consider whether they should stop at this point. It is pretty well authenticated that the Italians have provided themselves with a steel-plated target which even their 100-ton gun cannot penetrate, and that they are preparing a ship which shall be defended with this armor. In view of this circumstance, the authorities were recently deliberating upon the production of a much more powerful piece of ordnance, and it was anticipated that an order would be given before long to the Royal Gun Factories for a gun of over 200 tons. The drawings for such a weapon were prepared long since, the machinery is all prepared for constructing it, and all that is required is the order to proceed. Such a gun would throw a shot of some three tons weight, and pierce three feet of solid armor. It would, however, take two years to make, and perhaps another year for experiments; but the manufacture of a ship which would have a chance even with the guns of the present day would take at least as long. It is now, however, determined that a 200-ton gun shall not be made at Woolwich.—*Engineer.*

A New Piece of Heavy Ordnance.—The Washington *Herald* says:—The Ordnance Department of the Army has constructed a large rifled gun, weighing about 90,000 lbs., with a calibre of 12.25 inches, which is now undergoing proof at the Sandy Hook proving ground, under the direction and supervision of the Ordnance Board. So far the limited firings have developed the most satisfactory results. The gun is of cast iron, lined with a coiled wrought-iron tube, with a length of bore of 227 inches, and is mounted on a carriage of late design, with all the modern improvements to control recoil and to facilitate loading and manœuvering. Although as yet the firings have been limited, still enough is known of the power of the gun to say that for use against ironclads it is equal, if not superior, to any gun of the same calibre in any service. The essential features which contribute to any superiority over others in this respect are length of bore, character of projectile and powder. In the foreign services the English 12-inch wrought-iron gun has a length of bore of 198 inches; the Krupp calibre 12.008, has 222.5 inches; the Italian 12.6 has 252 inches; while the American is 227 inches long. This length adopted by the Ordnance Department gives all the usual effects that can be obtained from this source, and secures a thorough consumption of the maximum powder-charges, as has been practically proved by the absence of any unconsumed grains of powder after the discharge. The powders used have given marked superiority in velocities and pressures over those used in foreign services, the velocities being greater for corresponding pressures, and the pressures much less for the service charges. No undue pressures have shown so far from the use of the adopted system of projectiles, no erosion or guttering are apparent, and perfect rotation has resulted from the rifling and sabot employed; and this, with the absence of any stripping, has given that accuracy of flight so necessary for a successful rifled projectile. The energies attained, or rather the capacities for work—the gist of the whole subject—compare most favorably with those of foreign guns, although the difference in charges and weights of projectiles do not, so far, admit of a complete comparison; but enough is known to show that this gun has an equal, if not a greater, capacity for work of any of the foreign service rifles of like size. For instance, the English 25-ton gun has given less energy by, say, 450 foot tons, with 85 lbs. of powder and a 600 lb. projectile, than the American; and the Krupp, with 88 lbs. of powder and 664 lbs. of projectile, 1254 foot-tons less; while the Italian, with 100 lbs. of powder and 770 lbs. of projectile, has only yielded a little over 400 foot-tons more; and in these comparisons the American gun only uses 80 lbs. of powder with a 600 lb. shot. But with 110 lbs. of powder and 700 lbs. of projectile the American rifle gives 9551 foot-tons muzzle energy, or 246 foot-tons per inch of shots circumference, an energy about as great as any gun known for this charge, and decidedly superior to Krupp's and the Italian, using heavier charges. With these encouraging results, by developing a strong and durable system of gun construction, with our superior powder and projectiles, and with our rifling and length of bore, it would seem that the Ordnance Department has produced a weapon able to cope successfully with the best foreign guns, and at a much less cost.

The Electric Fuse and Heavy Cannon.—It seems as if we were about to abandon the old method of firing guns on board ship with the lanyard, and to use the electric fuse instead, at any rate, so far as heavy cannon are concerned. For some years past experiments have been carried on in the navy with electric firing, but it is only since we have had to do with very heavy guns, and particularly those in turrets, that this method of discharge has become almost indispensable. To be cooped inside a close iron turret in company with a pair of terrible weapons of 35 or 38 tons, and to experience the full measure of their thunder, is scarcely to be contemplated with indifference; yet this is not the reason, or at least not the principal reason, why the electric current is to be employed in future instead of the gunner's arm. The real cause is twofold; in the first place it is possible to take better aim by using electricity to do the work; and, secondly, the effect of the shots is more terrible. The simultaneous discharge of three or four projectiles against heavy armour has been found capable of penetrating the latter, when single shots are quite unable to do so. A vibration is set up in the iron plating, it is presumed, and in this condition the armor is more vulnerable. Simultaneous firing is impossible by hand and word of command, in the same way as gunners used to fire broadsides in the old three-decker days. To the ear the thunder of discharge might not appear otherwise in-

stantaneous, but the effect upon an ironclad is vastly different if a volley is fired by lanyards, or by a flash of electricity. The other reason is more important still. The guns are so close to the water, and the portholes so limited in size, that sighting along the weapons is frequently a matter of difficulty. The operation is much more easily performed by an officer stationed above, either in the rigging, or in the armored tower, with which most of our modern ironclads are fitted. Provided with suitable sights and electric wires which lead down into the batteries, the captain, or other officer of the ship, here has the whole of its armament under his hand. He directs at what angle the guns shall be laid, and, watching his opportunity, discharges them simultaneously at the instant he thinks most fit. Situated above the deck he is removed from the bustle and smoke below, and can act with more coolness and judgment, while obviously no time is lost when the critical moment for firing arrives.—*Standard.*

THE 6-INCH ARMSTRONG BREECH LOADER.—The experiments with a 6-inch breech-loader, submitted to the test by Sir William Armstrong, have been completed at Shoeburyness, to which place the gun was removed at the close of the preliminary experiments at the proof butts adjoining the Royal Arsenal, Woolwich, and the gun has been handed over to the maker. It has made some excellent practice, and the velocities recorded have been very high, heavy charges of pebble powder having been employed, with projectiles of from 60 lbs. to 70 lbs. in weight. The breech arrangement, which is on the French screw system, has been greatly improved by the introduction of the Elswick gas check, or "obdurator," a steel cup which expands in rear of the chamber and completes the gas-tight joint. The performance of the gun has satisfied the War Office authorities of its merits, though the simpler muzzle-loading system still has the preference, but at the same time the antipathy to breech-loading guns has so far abated that it has been decided to make a wholesale conversion of the old 32-pounder smooth bore cast-iron guns into breech-loading guns and to use them in flank defences. It has also been found more convenient to load these particular guns at the breech than at the muzzle, chiefly on account of its being necessary to mount them on carriages which do not recoil; they will fire heavy charges of case shot at short ranges.

ARMOR-PLATE TESTS.—On Tuesday, an armor-plate, manufactured by Messrs. Cammell and Co., of the Cyclops Works, Sheffield, and sub-carbonised according to the patent of that firm, was tested, by order of the Admiralty, on board the Nettle, target ship, in Portsmouth Harbor. Its dimensions were —7 feet ten inches, by 6 feet 6 inches; its thickness 9 inches, and its weight about eight tons. It was fixed to a transversal wood bulkhead, built from vertical and two horizontal layers of oak bulks, making in all 3 feet 6 inches of thickness, the whole being shored by substantial wooden spalls secured by a massive wooden thwartship. The gun used was a 12-ton 9 inch muzzle-loading rifle, and stood behind athwartship wooden bulkhead, 30 feet from the plate. The charges were 50 lbs. of battering pebble powder, and the projectiles shelled Palliser shots, 250 lbs. in weight; the muzzle velocity being 1420 feet per second, and the energy at the muzzle 3486 feet. The regulation number of rounds was fired at the plate, the experiments being conducted by Captain Herbert, of the gunnery ship Excellent, and the impact of the three projectiles formed a triangular diagram, each impact being about 2 feet apart. The first shot struck the centre of the right hand section of the plate, and penetrated 7¼ inches, producing two cracks which extended from the point of impact to either side of the plate, in a slightly downward direction, and that of infinitesimal width went through the entire thickness of the plate. The second projectile was aimed at the middle of the lower part of the plate. The penetration was not only equivalent to the thickness of the plate, but the shot entered 2¼ inches into the wooden backing, and considerably enlarged the two cracks, as well as loosened the left-hand corner of the plate. The final shot, however, was the most destructive in its consequences. Besides penetrating through the plate, and nearly 2 inches into the backing, it brought away almost one-fourth of the plate. The disjointure of this section commenced at the impact of the first shot, and ran in an irregular horizontal direction to the nearside, and downwards in a zig-zag fashion to the centre of the second shot, where it abruptly branched off to the lower edge of the left side of the plate. Two additional fissures were also occasioned in the upper part of the target. Mr. Wilson was present on behalf of Messrs. Cammell, and the experiments, which, judged by comparative data, was fairly satisfactory, although substantially less favorable than those with the last composite plate supplied by the firm, were watched with much interest by the captain and two chief officers of the German iron clad Konig Wilhelm.

BOOK NOTICES.

ELEMENTS OF DESCRIPTIVE GEOMETRY. By J. B. MILLAR, B. E. London: Macmillan & Co. Price $2.00. For sale by D. Van Nostrand.

This treatise begins with the elementary geometry of the plane; the first chapter containing about the same range of propositions as the sixth book of Davis' Legendre.

The common problems of, and straight line and plane in space are given in the second chapter.

Projections of plane and solid figures and solution of the spherical triangle form the topics of chapter third.

Curved surfaces, tangent planes and intersections of curved surfaces occupy chapters four and five, and complete the subject proper.

Axometric Projection is given in a brief appendix.

Altogether, it is an excellent work. Concisely written, beautifully printed, with excellent diagrams interspersed in the text.

METALS AND THEIR CHIEF INDUSTRIAL APPLICATIONS. By CHARLES R. ALDER WRIGHT, D. Sc London: Macmillan & Co. Price $1.25. For sale by D. Van Nostrand.

This treatise affords a brief outline of the metallurgy, natural history and industrial uses of most of the metals.

Chapter I: Describes metals and their sources. Chapter II: Metallurgy of the precious metals. Chapter III: Metallurgy of the more important base metals. Chapter IV: Metallurgy of the less important oxidizable metals. Chapter V: Physical properties of the metals. Chapter VI: Thermic and electric relations of the metals. Chapter VII: Chemical relation of the metals.

Thirty-three wood-cuts embellish the book.

L'EXPOSE DES APPLICATIONS DE L'ELECTRICITE. Par TH. DU MONCEL. Fifth volume. Paris, Lacroix. Price $5.60. For sale by D. Van Nostrand.

This large octavo is devoted as the title implies to *applications* of electricity.

The divisions of the subject consider in order the following topics: Railway Telegraphs; Mechanical Applications; Applications to the Arts; Applications to Domestic Economy; Production of heat; Electric Lightning, etc., etc.

Descriptions of machines and processes are given in the fullest manner.

One hundred and seventy wood-cuts and three folding plates illustrate the work, which covers in all 672 large octavo pages.

WATER, AIR AND DISINFECTANTS. By W. NOEL HARTLEY, F.R.S.E., F.S.C. London: Society for Promoting Christian Knowledge. Price 50 cts. For sale by D. Van Nostrand.

This is one of the Manuals of Health published by the above society, and it is a work which should be in every house, as the information supplied is of everyday application and nearly affects the wellbeing of all classes of society. Much, but not too much, space is devoted to water, and recent revelations have shown that the rich as well as the poor in London are liable to disease and premature death from impure water. The propagation of zymotic disease by water receives consideration, and a chapter is devoted to its purification. Next we have an inquiry into the properties and composition of air, and some valuable hints on ventilation. It may be thought by some that it is out of the province of a religious society to publish a scientific work, but it does not need much reflection to show that it is of little use instructing people even in common morality when their surroundings are such as may be seen in London and every large town. It is true that the study of this work cannot remedy faulty coustruction, but attention to its advice will do much to mitigate it. To quote the words of Mr. Simon, lately the Medical Officer to the Privy Council, "It is to cleanliness, ventilation and drainage, and the use of perfectly pure drinking water, that populations ought mainly to look for safety against nuisance and infection."

LE MASSIF DU MONT BLANC. PAR E. VIOLLET-LE-DUC. Paris; J. Baudry. Price $12.00. For sale by D. Van Nostrand.

The structure, geological and lithological of Mont Blanc and the group of which it is the culminating point, is the subject of this interesting volume.

It would seem from the amount of detail in the illustrations, as though every acre of the area had been carefully studied.

The action of the glaciers in recent times, as well as the evidences of more extensive wear by larger ice rivers in past ages, receives a fair share of attention.

The volume contains 275 pages of text, royal octavo size, and is illustrated by 120 wood-cuts.

There are also four charts exhibiting in colors the topography of the entire region described, with profiles across all the leading summits.

THE RAILWAY BUILDER. By WM. J. NICOLLS, Civil Engineer. New York: D. Van Nostrand. Price $2.00.

This is a neat pocket-book for the use of railroad men; and is designed to afford ready aid in estimating the cost of construction of every portion of the equipment of an American railway.

Special pains have been taken by the author to render the subject clear to readers who do not find in the algebraic formula as satisfactory expression of an engineering fact.

To quite a large class of practical railway men, this plan will be considered as an acceptable, if not a superior one.

An abstract of the table of contents is herewith given:

Chapter I. Field Operations; Corps of Engineers; The Transit; The Engineer's Level; Outfit; Running a Preliminary Line; Transit Book; Obstacles; Crossing a River; Curves; Table of Railway Curves. II. Preliminary Surveys; Locating the Line; Grant of Right of Way; Form of Contract and Proposal. III. Cost of Earthwork; Maximum Grade; Staking out the Work; Average cost of Excavating; Quantity of Earths equal to a Ton; Tunnels. IV. Permanent Way; Ballast; Table of Ballasting; Stringers; Cross-ties; Iron and Steel Rails; Tons of Rails required to lay one mile of Track; The Open Joint; Number of Rails and Joints per mile of Single Track; Fish Plates; Fish Plates and Bolts required for one mile of Single Track; Weight of Hot Pressed Nuts; Weight of Nuts and Bolt Heads; Bolt Heads, and Nuts; Spikes; Contract for Track Laying; Trestles; Bridges; Weight of Iron Bridges, Wooden Bridges; Foundations; Culverts. V. Frogs and Switches; Main Track and Siding; Switches; McCrea's Improved Chair; Frogs; Crossings; Signals; Interlocking Signals; The Block System. VI. Equipment; Locomotives; Railway Cars; Sleeping Cars; Average weight of Car; Coal Cars; Wheels; Table of Steel-tired Wheels; Wrought Iron Frames for Trucks; Couplings; Springs; Brakes; Automatic or Continuous Brake. VII. Depots

and Structures; Passenger Stations; Freight Depot; Way Stations; Flag Stations; Turntable; Water Stations; Fuel; Properties of Fuel; Coaling Platform; Engine House; Road Crossings.

MISCELLANEOUS.

THE Superintendent of the Westmoreland Coal Co., writes that a superior form of Air Duct to be used for ventilating mines, in connection with a hand fan, is in successful use in his district. It is a seamless cotton tube made by the Penn. Cotton Mill, at Pittsburgh.

WE understand that Mr. E. Roberts, of the *Nautical Almanac* office, has been requested by the India office to construct for use in India a self-acting tide-calculating machine. It will be designed not only to predict the tides at open-coast stations, but also river and shallow-water tides. It will be a great improvement on the tide-calculating machine at South Kensington (now temporarily at the Paris Exhibition), inasmuch as the tides caused by the smaller lunar perturbations will be included. Each component will be fitted with a slide, so that no error will be caused from the eccentricity of the pullies. The ordinates of the curves traced by the machine being as much as eighteen inches, the use of the slides is imperative. Mr. Roberts has calculated new numbers to represent the periods of the many components, and with such success, that the actual error of any one component, after a run representing a year's predictions, will not exceed the limit of error of setting the component at the commencement. The machine will be fitted with self-regulating driving-gear, so that it can be set at the close of the day and the whole year's curves be ready for reading off by the next morning. The machine is expected to be finished towards the end of the year. Now that the immense labor (the only objection raised against the employment of tidal predictions by harmonic analysis) is superseded, it is to be hoped that the Admiralty will avail themselves of an instrument, the results of which are so vastly superior to those now obtained with considerable labor by actual computation.

A PRACTICAL test of a fire-resisting flooring was on the 6th inst. made in Victoria Street, Westminster, for the information of the Metropolitan Board of Works. The Board has the power to refuse leave to architects to erect buildings of greater height than 100ft., an objection was made to the block called the "Members' Buildings," in Victoria Street, on the score of insecurity of life in case of fire. The objection was met by the provision of fire-resisting floors, and to prove that the means taken were secure was the purpose of Thursday's experiment. A square building with 9ft. brick walls had been erected on the open space to the west of Westminster Palace Hotel, the building represented the floor of a house with windows, doors, and a corridor. A room in this building contained a quantity of materials which were set on fire, and burned for upwards of an hour. The flooring to be tested formed the roof of the building, consisting of ordinary wooden joists, cased with terra cotta tiles, and there are in the system three open spaces between the ceiling of the one room and the flooring of the room above, the room above in the experimental room being, of course, open. While the fire was raging in the room and throwing out an intense heat, the gentlemen witnessing the experiment walked above the lighted room, and proved by the application of the hand to the topmost terra-cotta tiles that the heat had not penetrated, and that the fire was limited in location. Mr. Francis Butler, the architect of the Members'-Buildings, is the inventor, and it is stated that the invention has the merit of being inexpensive, costing about 50s for 100 feet square.

LIEUT. G. R. R. SAVAGE, R.E., writing from Rookee, North-West Provinces, India, sends us an account of some interesting experiments he has been making on long-distance telephones. He constructed telephones expressly for long-distance work, and succeeded in getting a bugle-call heard distinctly over 400 miles of Government telegraph line, the wire being one of the four or five main up-country telegraph wires which are carried on one set of posts. The telephones used, Lieut. Savage constructed with about 400 ohms of No. 38 guage wire, vibrating disc about 2½ inches diameter, the sending vibrating disc thicker a *little* than the receiving one. It seems to him right to oppose the work done at the receiving end as little as possible by having a very thin vibrating disc; while he had noticed that, *cæteris paribus*, a thicker disc approached to a telephone magnet gives a greater deflection on a distant very sensitive galvanometer, so long, of course, as it is not too thick. Lieut. Savage asks the reason for the following circumstance: Taking off the vibrating disc of a telephone, and tapping the magnet with any diamagnetic substance, brass, glass, &c., the tapping sound is heard distinctly at a distant telephone. This cannot be caused in the same way as the current in Prof. Bell's telephone; it must be caused, he supposes, by the particles of magnet being caused to vibrate longitudinally, and as the coil does not vibrate in unison with the particles of the magnet, the permanent lines of magnetic force must be cut by the coil, and hence a current. Hence, he asks, if this is the case, might not there be two causes combined producing the effect in Prof. Bell's telephone, both approach of disc and also longitudinal vibrations? Lieut. Savage constructed a small induction coil with soft iron core, the outer and inner coil the same. He heard and sent messages easily seventy or eighty miles by joining the two coils separately in circuit with the sending and receiving telephone. Of course there was no *increase* in any way, as no energy was expended on the current by the simple induction coil; there was a slight decrease in the sound. He thinks about 350 ohms of No. 38 wire makes the best coil for a telephone magnet ¼inch diameter.

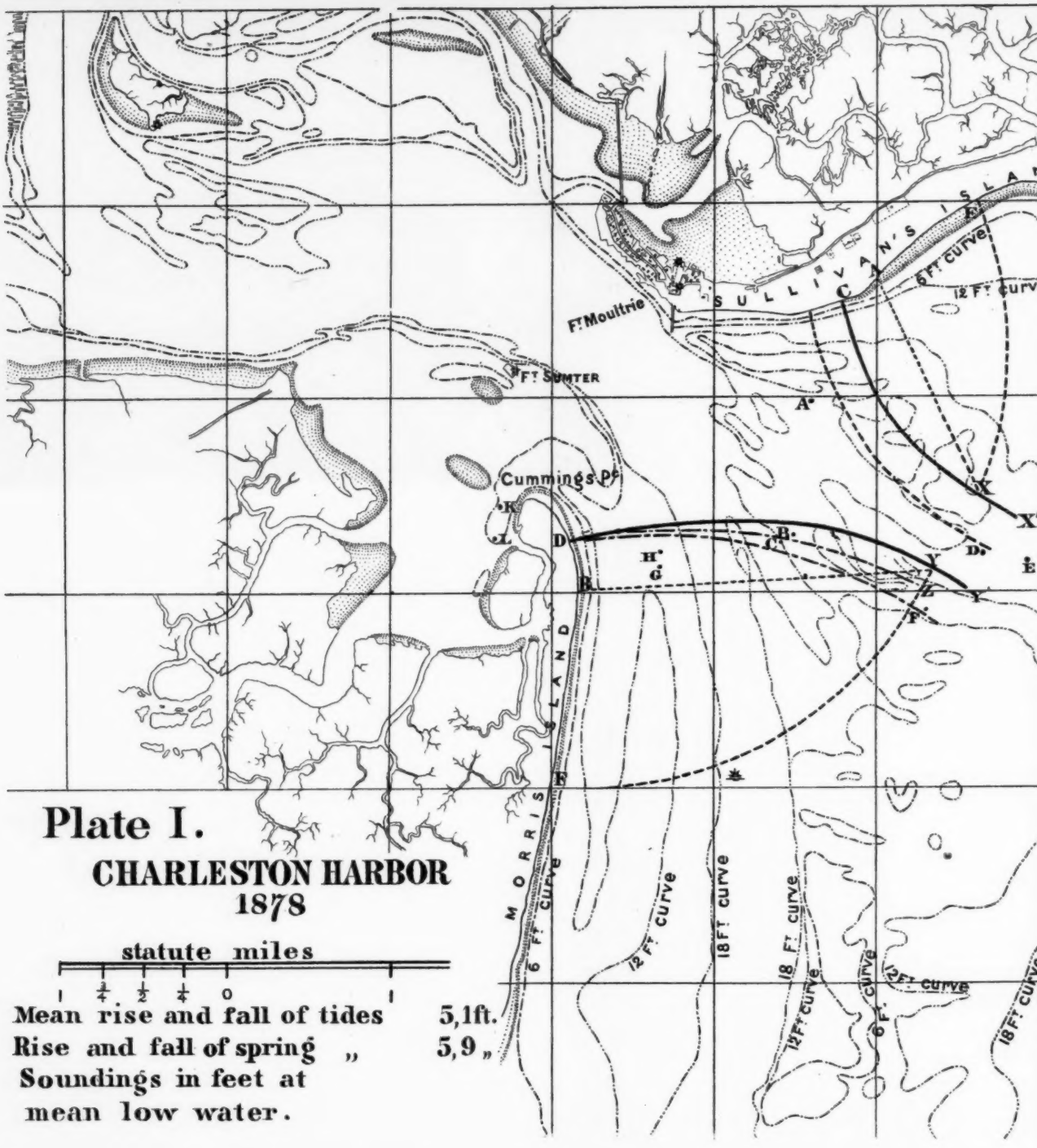


Plate I.

CHARLESTON HARBOR
1878

statute miles

1 ¾ ½ ¼ 0 1

Mean rise and fall of tides 5,1ft.
Rise and fall of spring „ 5,9 „
Soundings in feet at mean low water.

I S L A N D
12 Ft. curve
18 Ft. curve
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curve
18 Ft. curve

PROPOSED IMPROVEMENT
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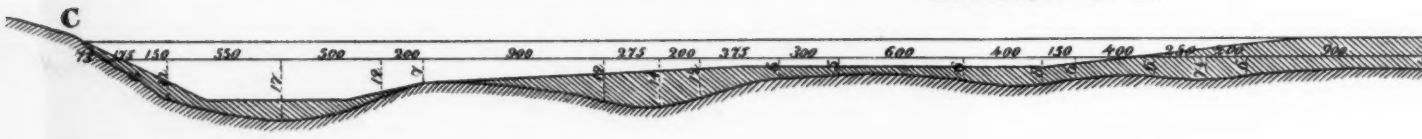
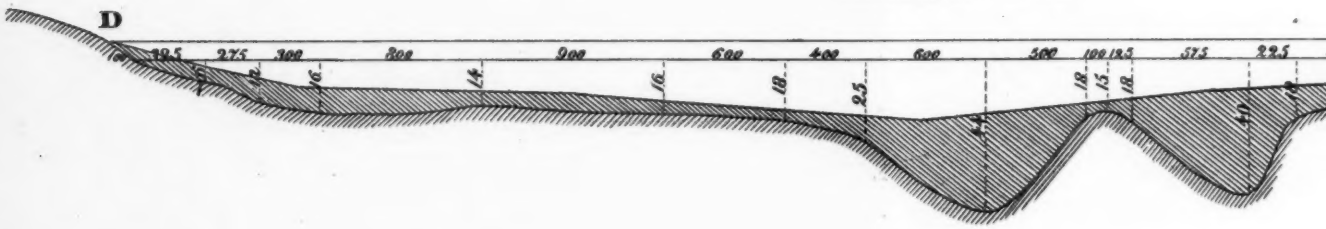
SECTION C–X



SECTION D–Y



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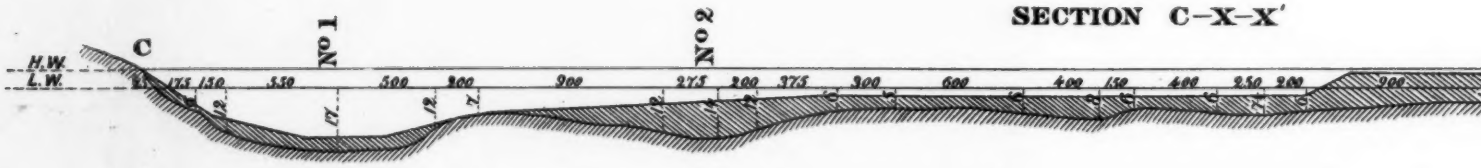

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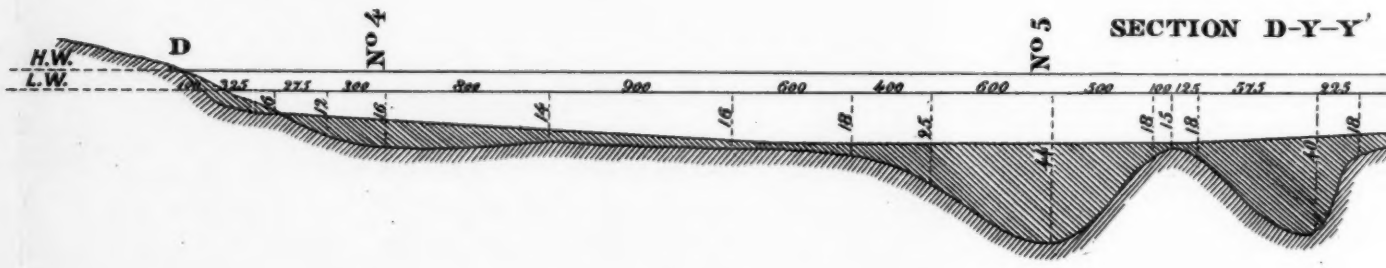
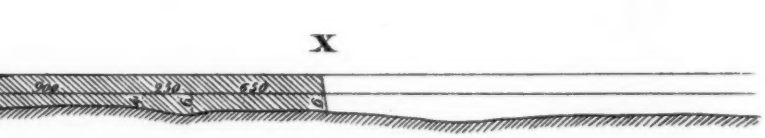
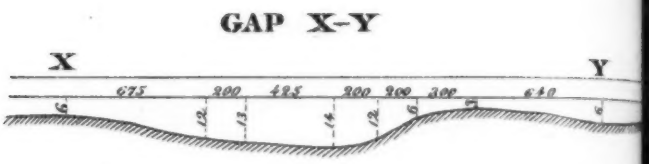
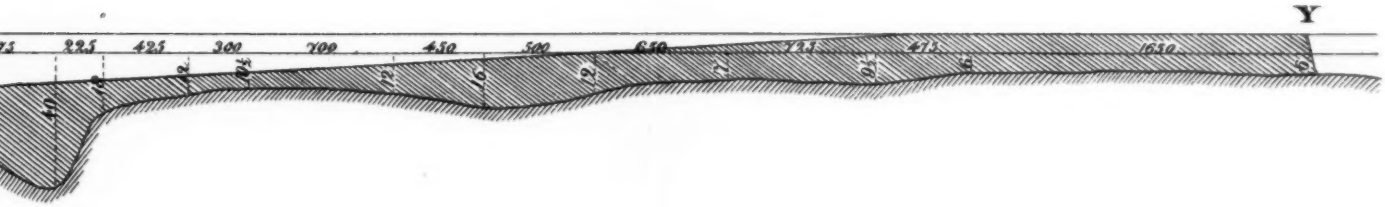


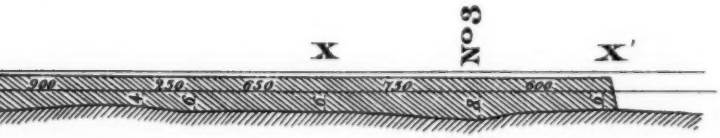
EMENT OF CHANNEL OF ENTRANCE
RBOR OF CHARLESTON S. C.

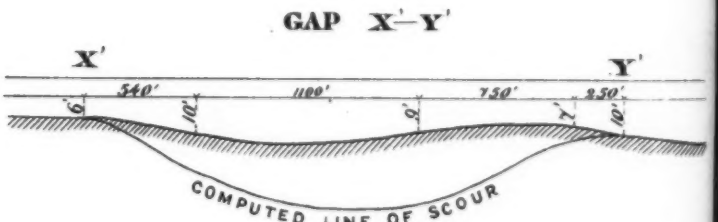
Plate II

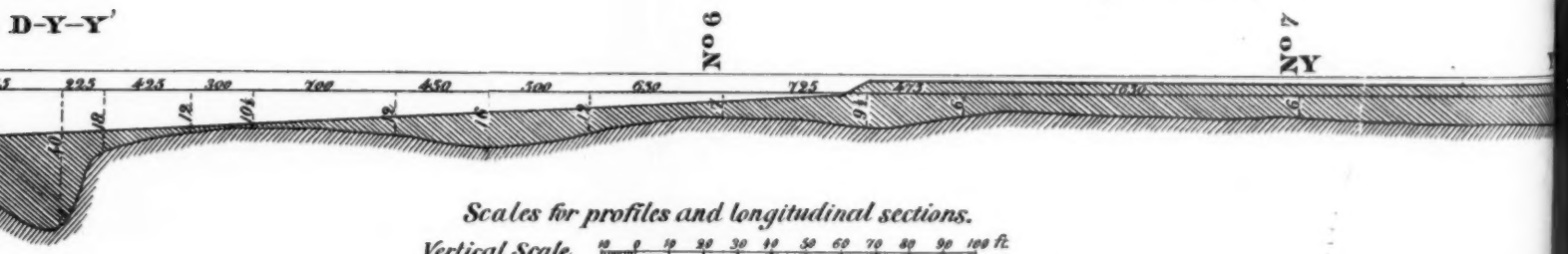












Scales for profiles and longitudinal sections.

Vertical Scale 10 0 10 20 30 40 50 60 70 80 90 100 ft.

Horizontal Scale 100 0 200 400 600 800 1000 1500 2000 ft.

PROPOSED IMPROVEMENT O
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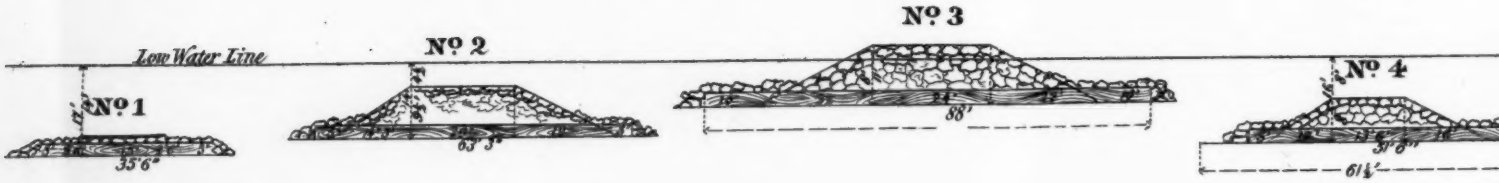
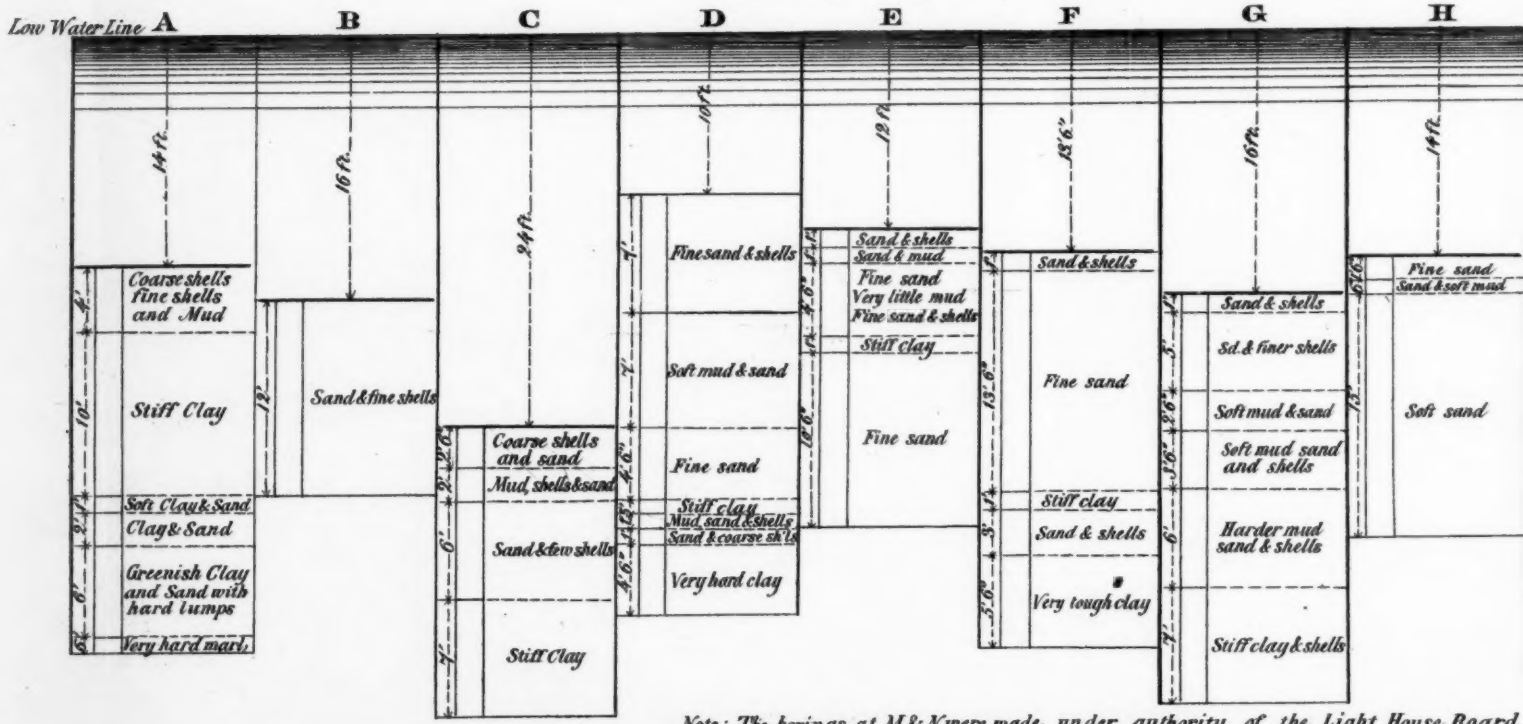
Plat

CROSS SEC



Borings at Charleston Harbor, S.C. at points.
indicated by corresponding letters and small circles on Plate I.



Note: The borings at M & N were made under authority of the Light House Board
All the other by Capt. J.C. Post under the orders of Lieut Col. Gillmore.

IENT OF CHANNEL OF ENTRANCE
OR OF CHARLESTON S. C.

Plate III

OSS SECTIONS

Scale for cross sections.

10 0 10 20 30 40 50 60 70 80 90 100ft.

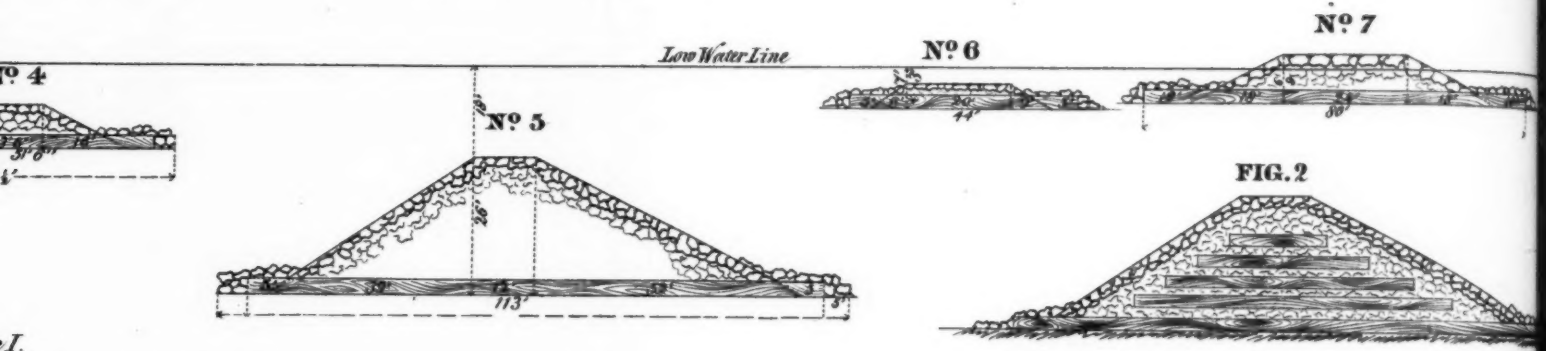
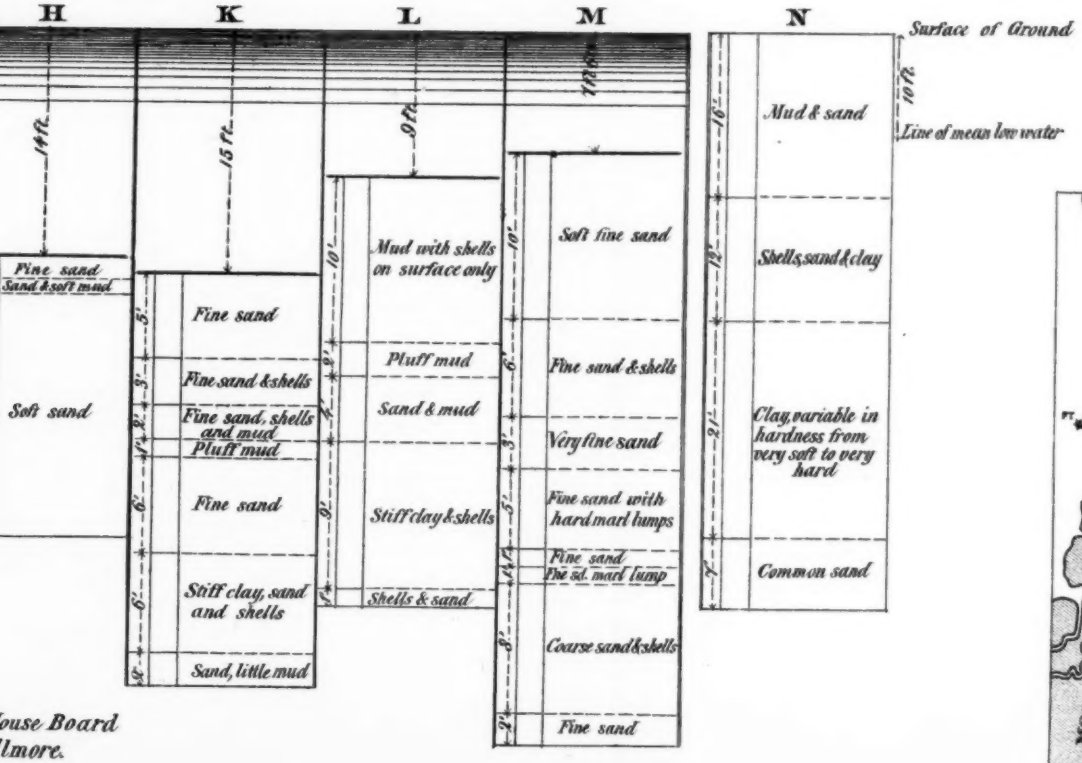


FIG. 2

I.



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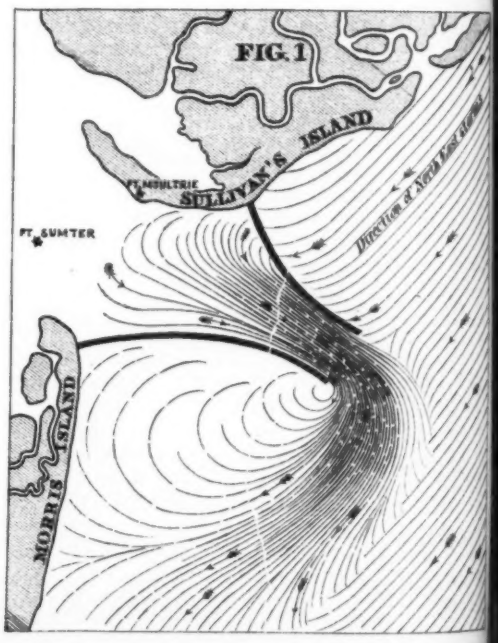
FIG. 1